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ST. LAWRENCE RIVER ENVIRONMENTAL INVESTIGATIONS

VOLUME 3

SEDIMENT QUALITY OF THE ST. LAWRENCE RIVER NEAR MAITLAND, 1984

FEBRUARY 1988

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ST. LAWRENCE RIVER ENVIRONMENTAL INVESTIGATIONS

VOLUME 3

SEDIMENT QUALITY OF THE ST. LAWRENCE RIVER NEAR MAITLAND, 1984

Report Prepared for:
Ontario Ministry of the Environment
Water Resources Branch
Great Lakes Section

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FOREWORD

This study was designed and supervised by P. Kauss of the Great Lakes Section, Water Resources Branch. Laboratory analysis was performed by staff of the Laboratory Services Branch.

This report has been reviewed by staff of the Water Resources Branch, Ontario Ministry of the Environment.

Recent sport fish data from the Maitland area indicate a reduction in lead levels in fish. The Ontario consumption advisory for lead levels in fish has been lifted as of 1987. Contaminant contributions from Lake Ontario to the St. Lawrence River are presently being assessed as part of a joint Ontario Ministry of the Environment/Environment Canada project. Tnis study involves developing a whole lake mass balance model for Lake Ontario including fate and transport of toxic contaminants in water, sediment and biota.

ACKNOWLEDGEMENTS

This study was funded in part by Environment Canada under the terms of the Canada-Ontario Agreement on Great Lakes Water Quality. The author would like to express his appreciation to C. Luck for the graphics and to J. Anderson, K. Sherman, P. Kauss, W. Scheider and D. Persaud for reviewing the manuscript.

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1. SUMMARY

The discovery of high lead levels in fish from the St. Lawrence River near Maitland in 1983 prompted a series of studies by the Ontario Ministry of the Environment in the area in 1984. This report discusses the results of sediment samples collected from 5 km upstream of the Dupont petrochemical and tetraethyl lead plants to 14 km downstream.

No major changes in sediment quality were observed between 1984 and an earlier, more limited 1975 MOE survey. The sediment lead plume attributable to the Dupont tetraethyl lead plant extended about 3 km downstream of the outfall. Elevated levels of HCBs, oil and grease and copper extended lesser distances. Now that the TEL plant has been closed (1985), lead levels in fish and sediment are expected to decline. The HCBs, oil and grease and copper may be associated with the continuing effluent from the Dupont monomer outfall and require further controls.

Most parameters in the study area had a distribution of elevated levels indicative of a source upstream. There is evidence to suggest that the source is suspended particulate matter from Lake Ontario that is not retained within that lake's depositional basins. The supply of contaminants is sufficiently large that a major point source of lead like Dupont did not generate the highest sediment lead concentrations found in an Environment Canada 1975 survey of the St. Lawrence River. Substantially elevated levels of most heavy metals, PCBs and other organochlorine compounds are attributed to Lake Ontario.

2. CONCLUSIONS AND RECOMMENDATIONS

1. The sediment chemistry of the St. Lawrence River near Maitland has not changed substantially between 1975 and 1984. The Nitrochem plant outfall did not have any discernible impact on sediment chemistry in the 1984 survey. The Dupont discharges created a 3 km plume of elevated lead levels and had a smaller impact on sediment levels of HCBs, oil and grease, copper, and possibly PCBs, cobalt, and total Kjeldahl nitrogen.

   Dupont's discharge of HCBs, oils (ether solubles), copper and possibly PCBs should be quantified and controlled.

2. All parameters examined had a depositional pattern consistent with a major source upstream of the study area. The probable source of the contaminated sediments not associated with local inputs is suspended particulate matter from Lake Ontario which was not retained by the depositional basins of the lake. The contaminated particulates may move downstream as bed load and thus avoid detection in most conventional water samples. The quality and quantity of suspended and bed load particulate entering the St. Lawrence River from Lake Ontario should be determined. The information has important implications for the contaminant budget for Lake Ontario and represents a contaminant loading to the St. Lawrence that appears to be significant.

3. High lead levels in fish at Maitland can be expected to decline with the cessation of alkyl lead loadings to the area and transport of contaminated sediments downstream. Research on the uptake of lead from sediments by fish should continue in order to determine safe sediment total and alkyl lead concentrations. At this time it is not clear if alkyl lead in sediment is the only form which is sufficiently biologically available to cause levels of concern in fish nor are the mechanisms understood which govern the stability

(destruction and possibly creation) of alkyl lead in sediments.

4. Since the shutdown of the TEL plant in 1985 the sediment lead associated with the outfall has probably dispersed downstream. In 1984 less than 1% of the lead emitted during the twenty year operation of the plant remained within the study area and some 400 tonnes had been transported downstream. The distribution of lead in the St. Lawrence River suggests that the Lake Ontario contribution has been even greater. Since lead in sediment has been shown to contribute to lead in biota it would be appropriate to study the transport of lead through the St. Lawrence River to its final depositional area and examine its impact on biota en route.

5. A fish consumption advisory for the St. Lawrence River will remain in effect due to elevated mercury and PCB levels in older fish of some species. Transport of mercury and PCB's from Lake Ontario should be examined as a possible contribution to those levels.

6. Future trace contaminant surveys, particularly in large river systems, should examine more compartments than the sediments. At a minimum the effluent loading and the background geochemistry should be well understood. An estimate of the suspended load and the bed load and the contaminants associated with those compartments is necessary to establish any contaminant "budget."

   To assess the direct impact of effluents a benthic invertebrate survey is appropriate. In this study area benthic invertebrate surveys have been used succesfully for many years. Recent studies have shown that benthic surveys employing SCUBA divers with airlift devices are the most efficient over the variety of substrates encountered in this survey area. Contaminant uptake is best

1. RÉSUMÉ

La découverte de concentrations élevées de plomb dans le poisson du Saint-Laurent près de Maitland en 1983 a donné lieu à une série d'études du ministère de l'Environnement dans ce secteur en 1984. Le présent rapport expose les résultats d'analyse des échantillons de sédiments prélevés entre un point situé à 5 km en amont des usines de plomb tétraéthyle et de pétrochimie de la société Dupont et un autre situé à 14 km en aval de ces usines.

Aucun changement majeur n'a été observé dans la qualité des sédiments entre 1984 et 1975, date à laquelle le ministère de l'Environnement avait réalisé une autre enquête de moindre envergure. La veine de plomb sédimentaire imputable à l'usine de plomb tétraéthyle de la société Dupont s'étendait sur environ 3 km en aval de l'exutoire. Les concentrations élevées d'hexachlorobenzène, d'huiles, de graisses et de cuivre s'étendaient sur des distances moindres. Étant donné la fermeture de l'usine de plomb tétraéthyle (1985), on s'attend à une diminution des concentrations de plomb dans le poisson et dans les sédiments. Toutefois, il est possible que l'hexachlorobenzène, les huiles, les graisses et le cuivre proviennent de l'effluent continu de l'exutoire de l'usine de monomères Dupont et nécessitent d'autres mesures de réduction.

Pour la plupart des substances étudiées, la répartition des concentrations élevées indique l'existence d'une source en amont. Il s'agirait de particules en suspension qui proviendraient du lac Ontario et ne seraient pas retenues par les bassins de sédimentation du lac. La quantité de polluants qui proviennent du lac Ontario est si grande qu'une source ponctuelle majeure de plomb comme Dupont n'a pas produit les concentrations de plomb sédimentaire les plus élevées observées lors d'une enquête sur le Saint-Laurent réalisée par Environnement Canada en 1975. Des concentrations assez élevées de la plupart des métaux lourds, de BPC et d'autres composés organochlorés sont attribuées au lac Ontario.

2. CONCLUSIONS ET RECOMMANDATIONS

1. La chimie sédimentaire du Saint-Laurent près de Maitland n'a pas changé de façon notable entre 1975 et 1984. L'exutoire de l'usine Nitrochem n'a eu aucun effet observable sur la chimie des sédiments d'après les analyses de 1984. Les déversements de Dupont ont créé une veine de plomb concentré sur trois kilomètres et ont eu un effet moindre sur les concentrations sédimentaires d'hexachlorobenzène, d'huiles, de graisses, de cuivre, et probablement de BPC, de cobalt et d'azote Kjeldahl total.

   Il y aurait lieu de mesurer et de réduire les quantités d'hexachlorobenzène, d'huiles (produits solubles de l'éther), de cuivre et, éventuellement, de BPC déversées par Dupont.

2. Tous les paramètres examinés laissent croire à l'existence d'une source majeure en amont de la zone étudiée. Ainsi, les sédiments pollués qui ne sont pas imputables aux sources locales seraient attribuables à des particules en suspension en provenance du lac Ontario qui n'auraient pas été retenues par les bassin de sédimention du lac. Les particules polluées peuvent être charriées et ainsi passer inaperçues dans la majorité des échantillons d'eau ordinaires. Il y aurait lieu d'évaluer la qualité et la quantité des particules qui passent du lac Ontario au Saint-Laurent en suspension et par charriage. Ces renseignements auraient en effet une grande importance pour le bilan de pollution du lac Ontario, et probablement aussi une certaine importance pour la pollution du Saint-Laurent.

3. On peut s'attendre à une réduction de la concentration du plomb dans le poisson à Maitland avec la cessation du déversement d'alkylés du plomb dans la région et avec le

transport des sédiments pollués en aval. Il y aurait cependant lieu de poursuivre les recherches sur l'absorption par les poissons du plomb contenu dans les sédiments en vue d'évaluer les concentrations sédimentaires d'alkylés du plomb et de plomb total qui ne présentent pas de danger. Pour le moment, on ne sait pas avec certitude si les alkylés du plomb dans les sédiments constituent le seul facteur biologique suffisamment répandu pour détériorer la qualité du poisson, et on ne comprend pas non plus les mécanismes qui régissent la stabilité (destruction et, peut-être, création) des alkylés du plomb dans les sédiments.

4. Depuis la fermeture de l'usine plomb tétraéthyle en 1985, le plomb sédimentaire provenant de l'exutoire de cette usine s'est probablement dispersé en aval. En 1984, moins de 1 % du plomb déversé au cours des vingt ans d'exploitation de l'usine se trouvait toujours dans la zone étudiée; quelque 400 tonnes de ce plomb avait été transportées en aval. La répartition du plomb dans le Saint-Laurent laisse croire que la contribution du lac Ontario a été supérieure. Puisqu'il est démontré que la présence de plomb dans les sédiments contribuait à la présence de plomb dans le biotope, il serait approprié d'étudier le transport du plomb le long du Saint-Laurent jusqu'à sa zone de dépôt final, et d'examiner les effets de ce transport sur le biotope au cours du trajet.

5. L'avertissement relatif à la consommation du poisson du Saint-Laurent demeurera en vigueur en raison des concentrations élevées de mercure et de BPC que recèlent les poissons âgés de certaines espèces. Il faudrait vérifier si ces concentrations peuvent être dues en partie aux polluants provenant du lac Ontario.

6. Les prochaines enquêtes sur les polluants à l'état de trace, en particulier dans les grands réseaux fluviaux, ne

devraient pas se limiter à l'examen des sédiments. Il faudrait au moins bien connaître les modes de déversement des effluents et la géochimie de fond. Il est nécessaire de disposer d'une évaluation des matières en suspension et du charriage, ainsi que des polluants associés à ces éléments, pour établir un "bilan" de pollution.

Il serait opportun d'entreprendre une enquête sur les invertébrés benthiques afin d'évaluer les effets directs des effluents. On réalise avec succès depuis nombre d'années des enquêtes sur les invertébrés benthiques dans cette zone limitée. Les études récentes démontrent que les enquêtes benthiques menées par des plongeurs équipés d'appareils à émulsion d'air sont les plus efficaces compte tenu de la diversité des substrats trouvés dans ce secteur. L'évaluation de l'arrivée de polluants se fait le mieux par diverses techniques d'évaluation biologique sur place.

Pour les enquêtes sur les polluants, les analyses granulométriques effectuées en laboratoire (qui ne permettent pas de faire la distinction entre l'argile à blocaux dure et la terre tourbeuse molle) sont moins utiles qu'une description complète du terrain conforme à des méthodes standard reproductibles.

examined by various in-place bioassessment techniques.

For contaminant surveys a laboratory grain-size analysis (which fails to distinguish between hard clay till and soft muck) is less useful than a complete field description which follows standard reproducible methods.

3. INTRODUCTION

3.1 Rationale

In 1983, Federal Government researchers found high lead levels in fish taken from the St. Lawrence River downstream of Maitland, Ontario. The suspected source of the problem was the waste discharge from Dupont of Canada's operation which produced tetraethyl lead as a gasoline additive. The Ontario Ministry of the Environment initiated a series of studies in 1984 to determine the source of the lead and the contaminant uptake routes to the fish. The primary study reported here is a survey of bottom sediments from Maitland 5 km upstream of the Dupont outfall to an area downstream of Prescott 14 km from the outfall. The study design included an examination of alkyl lead in sediments as well as total lead to clarify the uptake pathway to fish, however, a satisfactory lab analytical method was not developed. A secondary aspect of the study was a general evaluation of sediment quality for comparison with an MOE survey undertaken in 1975 (Griffiths, 1978).

3.2 Historical Background to Problem

The tetraethyl lead plant was part of a larger Dupont petrochemical complex producing nylon intermediates, acrylic fibres, spandex fibres and chlorinated fluorocarbons. The petrochemical complex began operation in 1953 and the tetraethyl lead plant came on stream in 1965. Upstream of Dupont is the Nitrochem nitrogen fertilizer complex (previously Genstar and before that Brockville Chemicals) producing ammonia, hydrogen, nitric acid, ammonium nitrate, urea and nitrogen solutions. A 1975 MOE survey of water quality, sediment quality and benthos attributed adverse impacts to both companies' effluents. The Genstar zone of influence extended 2 km until it impinged on the Dupont plumes. In the water column it resulted in elevated levels of ammonia, organic nitrogen and

nitrates. The sediments has elevated levels of nitrogenous compounds, mercury, copper, zinc and lead and a high chemical oxygen demand (COD). The zoobenthic community showed reduced species diversity.

A zone of influence of approximately 1 km characterized by elevated sediment lead levels and a depressed zoobenthic community was attributed to the Dupont tetraethyl lead plant discharge. A larger zone of influence extending more than 2 km and beyond the study area was attributed to the Dupont monomer outfall. Elevated sediment levels of cobalt, zinc, iron, and copper were reported in the zone of influence where the species diversity of the zoobenthic community was reduced and the number of taxa depressed. The 1975 study recommended that Dupont reduce lead in its discharge and that both Genstar and Dupont assess the levels of other heavy metals in their effluents and take corrective measures as necessary.

3.3 Description of the Study Area

Figure 1 shows the study area located about 88 km below the outlet of Lake Ontario. The river is the outlet of the entire Great Lakes drainage system (766,600 sq km upstream of Cornwall) having a mean annual discharge in the order of 6217 m3/sec with a range in the mean daily maximum and minimum discharge between 6709 and 4643 m3/sec. In the study area the river is about 1750 m broad with a mid channel depth of 20 m. The substrate in the main channel (where stream velocity is in the order of 0.3 m/sec and sufficient to erode and transport sand size particles) is hard clay, rock and gravel overlain by a discontinous thin layer of finer sediments. Closer to shore where stream velocities are lower some areas have accumulated deep deposits of silt and organic matter. The shelf along the Canadian shore extending out to about the 6 m depth contour supports aquatic macrophytes.

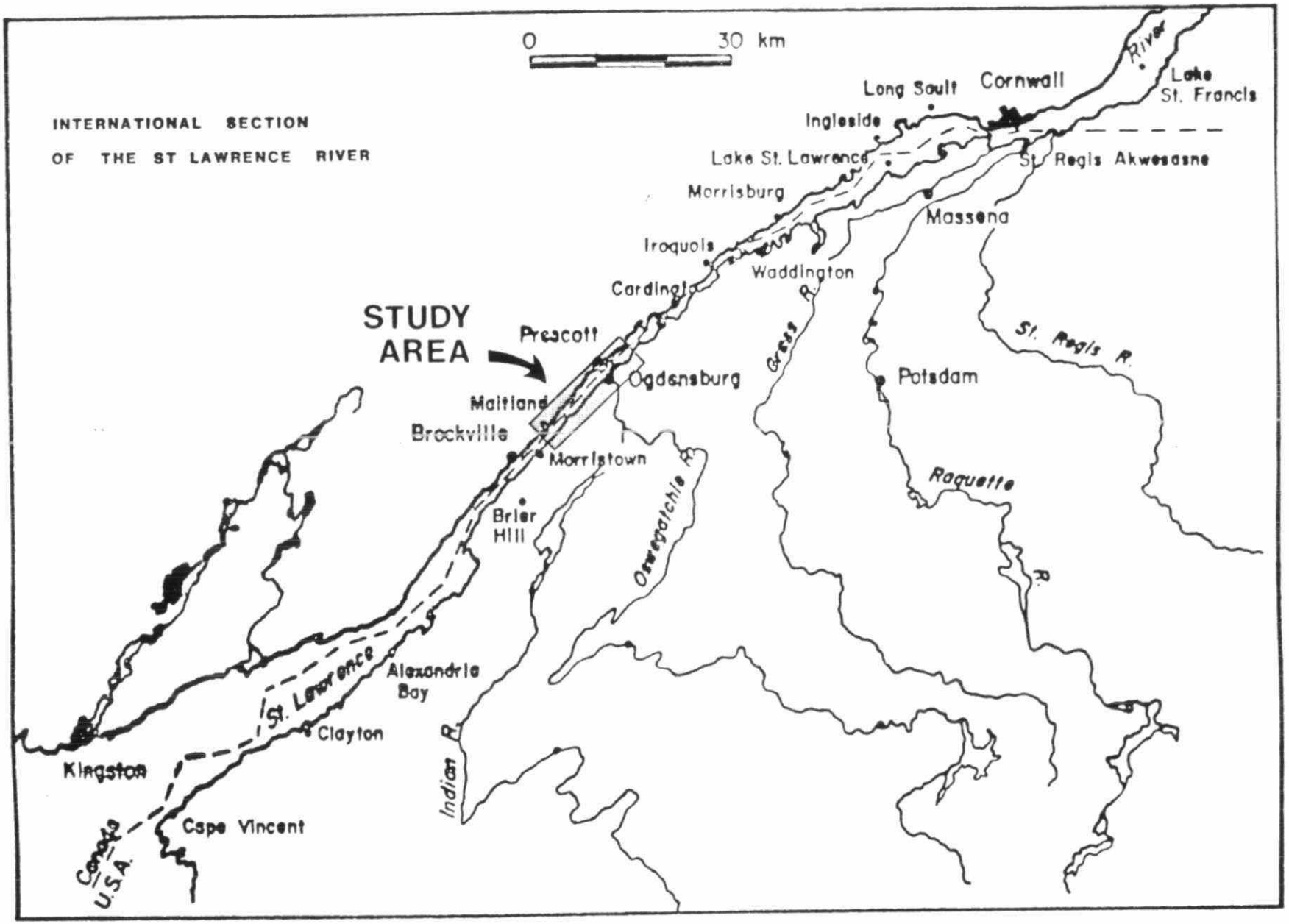


FIGURE 1 : STUDY AREA

The contaminant transfer characteristics of the St. Lawrence River in relation to the rest of the Lower Great Lakes-St. Lawrence River Corridor are well described by R.J. Allen (1986). Essentially the river acts as a conduit for inputs from Lake Ontario and local sources, transporting them to the Gulf of St. Lawrence. Interim "storage," perhaps for a matter of years, occurs in the shallow riverine lakes St. Francis, St. Louis, and St. Pierre downstream of study area.

3.4 Water Users

The St. Lawrence River in the study vicinity is used for municipal and industrial water supply, waste disposal, commercial shipping, recreational boating, swimming and sport fishing. Blue Church Bay, (also referred to as Little Church Bay in some earlier reports) just 1.5 km downstream of Dupont, supports a popular sport fishery. In 1985 the Ministry of the Environment issued a fish consumption advisory that all sportfish in the Blue Church Bay/Maitland area should be eaten on an occasional meal basis only (1 or 2 meals per month for long-term consumption and not at all for children under 15 years and women of childbearing age) (MOE/MNR, 1985). The recommendation was issued on the basis of lead (in particular alkyl lead) levels in the edible portion of sportfish caught in the area in 1983 and 1984.

Figure 2 gives the location of the intakes and outfalls in the study area. Nitrochem Inc. discharges approximately 2.9 million l/day via its submerged outfall at Claybank Bay at the 6 m water depth. From 1975 until June 1985 Dupont combined 9 million l/day from the tetraethyl lead plant with 145 million l/day of cooling water and monomer plant wastes before discharging the combined flow through twin 1.22 m diameter outfalls extending 104 and 120 m offshore to the 6.8 km depth contour. In its early years of operation (1965 to 1970) the TEL plant discharged about 117 kg of lead per day to the river. This loading was gradually reduced to about 18 kg per day in 1984. The total amount of lead emitted from plant start-up to the 1984 survey is estimated by this author at 406,000 kg. In June 1975 the company stopped processing new material and for the next 60 days processed sludge as they decommissioned the TEL plant. In February 1986 Dupont sealed the pipes from the tetraethyl plant (per comm. J. Pruner M.O.E.). Dupont's sanitary waste is treated at a small (0.27 million l/day) on-site sewage treatment plant and discharged through an offshore outfall downstream of the main outfalls.

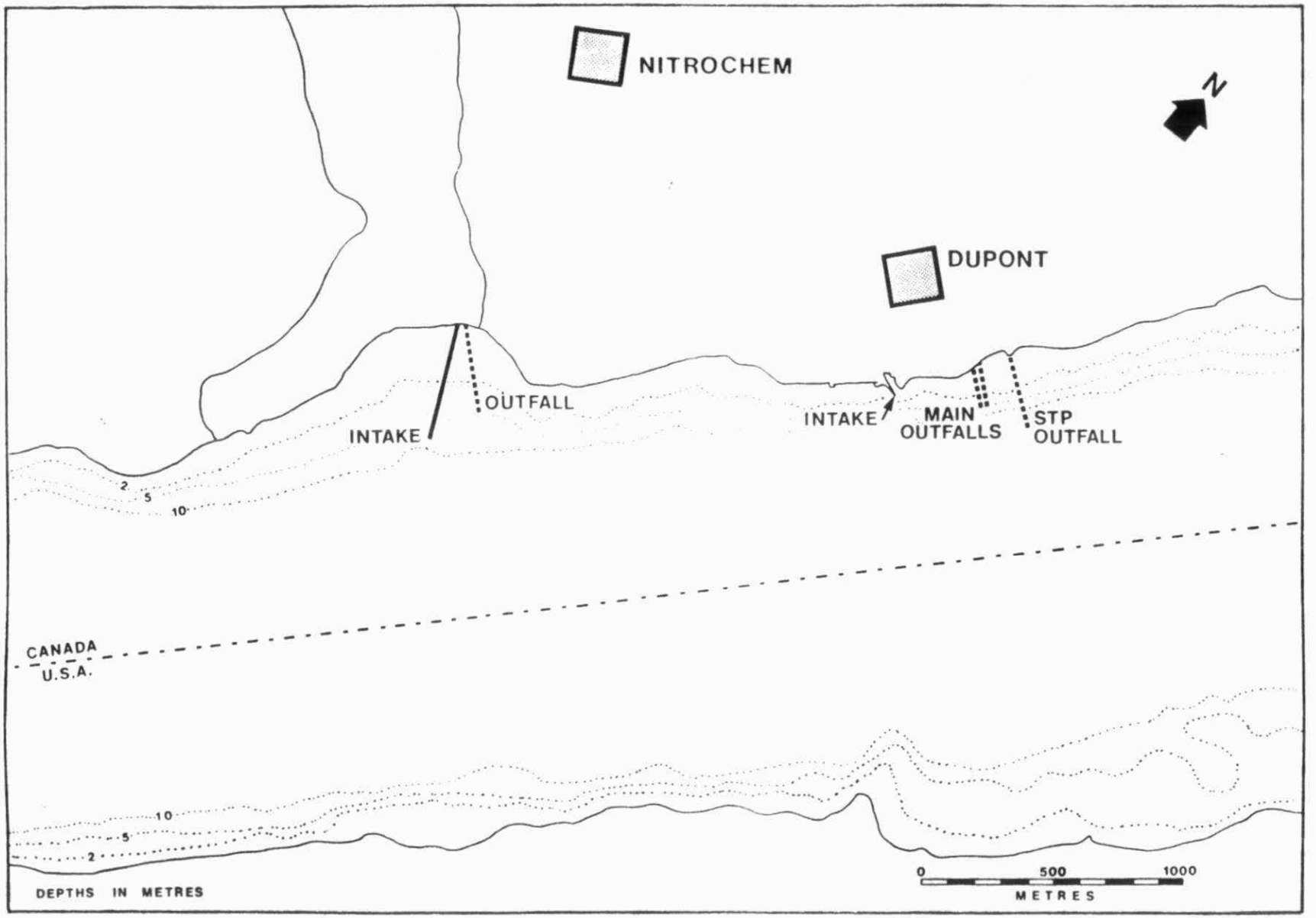


FIGURE 2 : INTAKES AND OUTFALLS IN THE STUDY AREA

Ships carry as much as 215 million tonnes/year of cargo through the study area including grain, iron ore, coal, petroleum products and manufactured goods. The study area includes the Prescott anchorage area and various sites which are occasionally dredged to maintain navigable depths.

4. METHODS

4.1 Field Methods

Sixteen transects were selected from Maitland to Johnstown as shown in figure 3. Sediment sampling stations along each range were generally at the following depths (from the Canadian shore) 2 m, 9 m, 18 m, deepest, 9 m, 2 m for a total of 74 stations.

Three or more Shipek grab samples were collected at each station between May 30 and June 5, 1984. The top 3 cm of the Shipek samples were subsampled with a solvent and distilled water rinsed stainless steel sampler. The subsamples were combined in a similarly pre-rinsed glass bowl and mixed well with a pre-rinsed stainless steel stirrer. After removal of large objects like clams and twigs the combined sample was divided among wide-mouth glass jars for transport to the MOE laboratory. At 6 of the 74 stations sufficient sample was collected to submit duplicate samples for analysis.

Dupont provided daily effluent flows and lead concentrations. Effluent samples were collected at 10 minute intervals by a Markland "Duckbill Sampler" and composited over a 24 hour period. Analyses of these samples were performed by Atomic Absorption Spectrometry. The effluent volume was estimated from daily meter readings of the incoming water to the plant.

4.2 Laboratory Methods

All sediment samples were analysed at the Toronto MOE laboratory using standard MOE analytical methods (MOE 1983) for the following parameters: grain size; loss on ignition (LOI); total organic carbon (TOC): total phosphorus (TP); total Kjeldahl nitrogen (TKN): oil and grease (solvent extractables); iron (Fe); arsenic (As); cadmium (CD); cobalt (Co); chromium (Cr); copper (Cu); mercury (Hg); nickel (Ni); zinc (Zn); lead (Pb); PCBs;

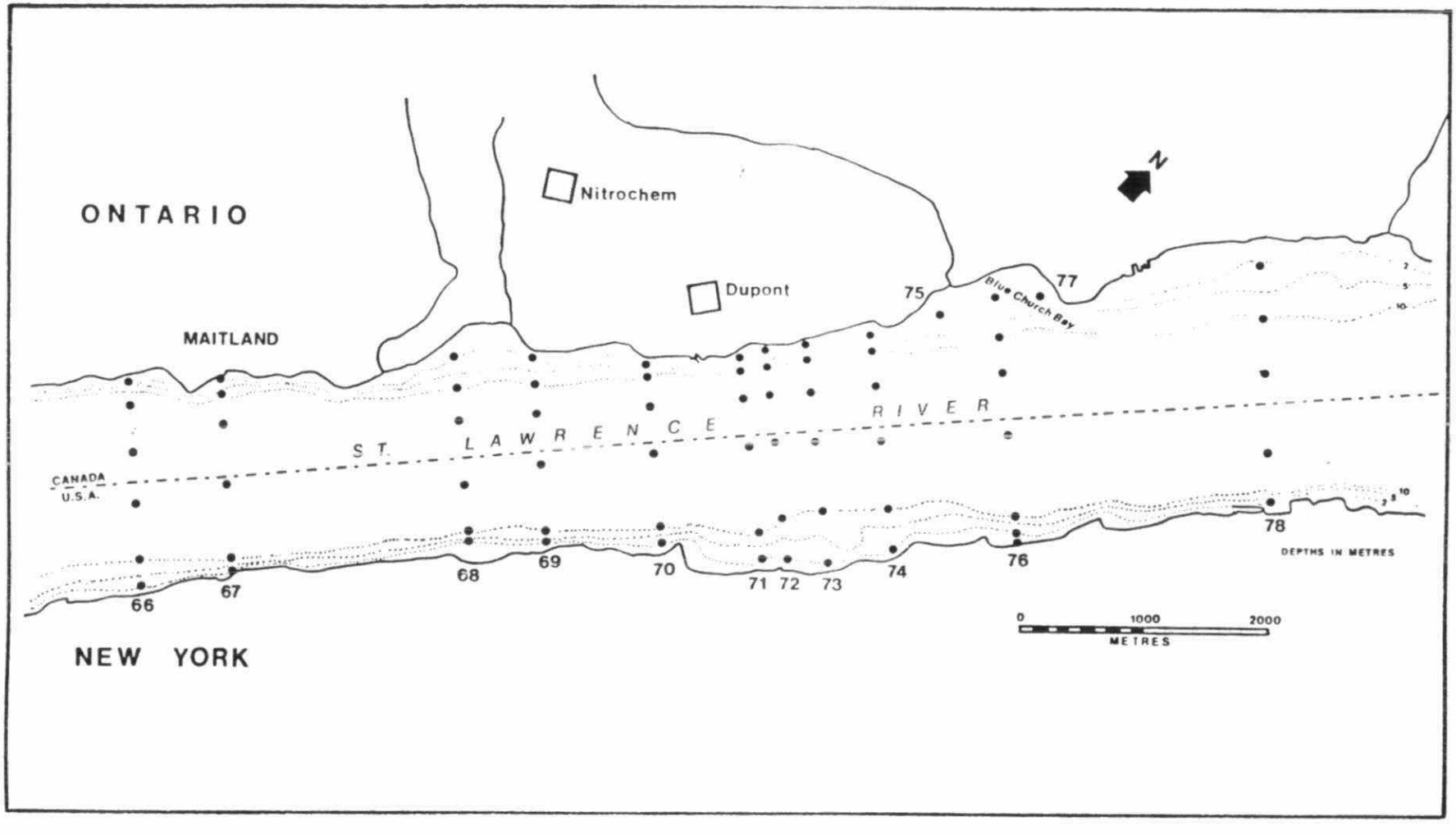


FIGURE 3A : SAMPLE LOCATIONS

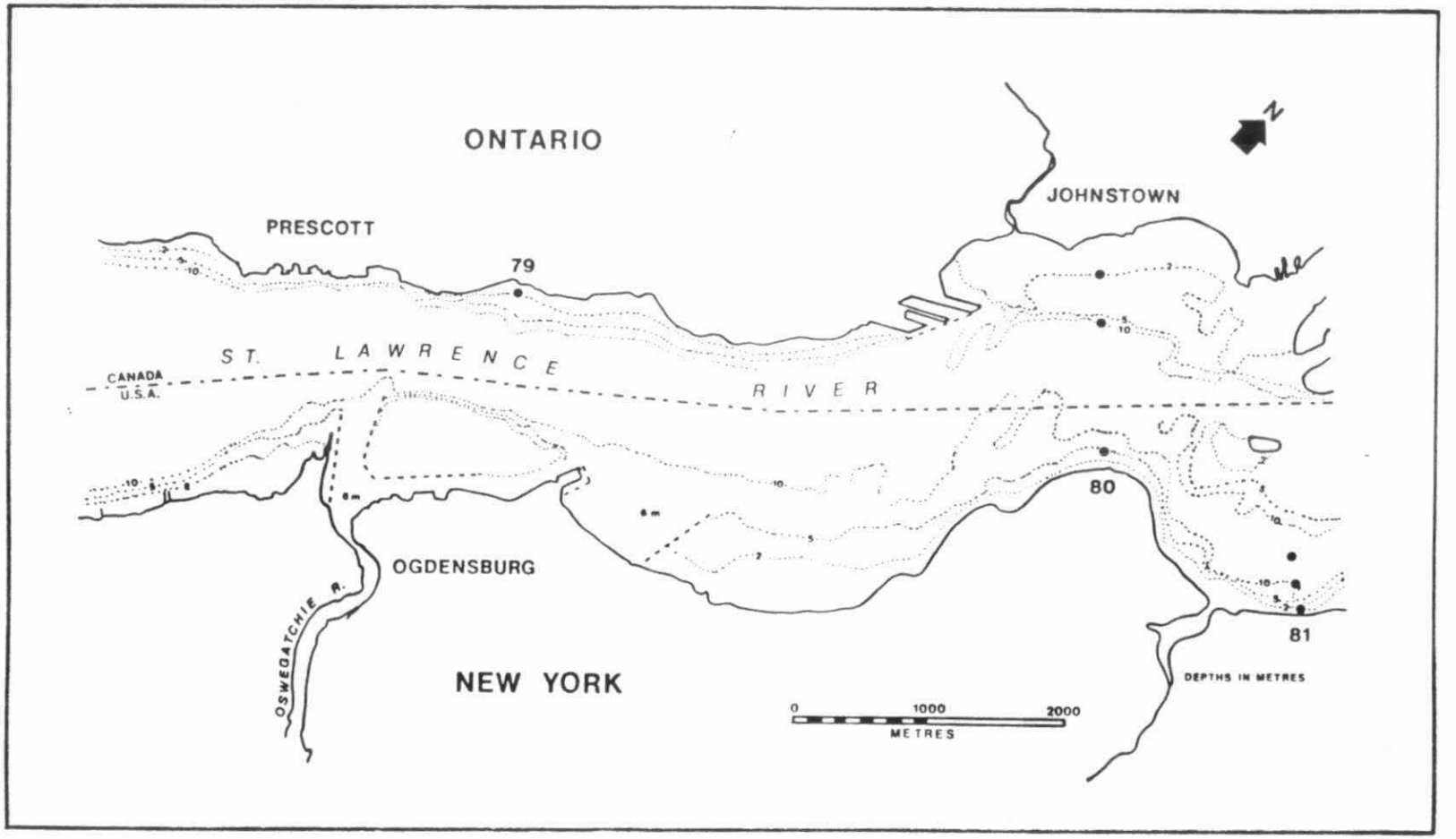


FIGURE 3B : SAMPLE LOCATIONS

hexachlorobenzene (HCB); heptachlor; aldrin; mirex; ppDDE; dieldrin; endrin; alpha, beta, and gamma BHC; alpha and gamma chlordane; oxychlordane; opDDT; ppDDT; ppDDD; methoxychlor (DMDT); heptachlor expoxide; endosulphan I, II, and sulphate. All results are reported on a dry weight basis.

5. RESULTS

5.1 Sediment Physical Characteristics

Figure 4 shows the results of the laboratory grain size analysis. Appendix A provides supplementary information from the field notes in terms of layering and texture. The sediments in shallow water near shore are sand with small percentages of silt and clay. The deepwater samples contain increasing amounts of clay size particles although silts rarely account for more than 15% of a given sample. The deepest stations usually contained shells and gravel in addition to the clay and required multiple grabs to obtain sufficient sample for analysis. The field notes describe two areas of soft bottom or "ooze" consistency. The first such area includes the 2 m and 9 m depth stations at Range 67 in Maitland Bay and extends to (or re-occurs at) the 9 m depth station of Range 68 in Claybank Bay.

The second "ooze" area occurs near the American shore and includes the 2 m and 9 m stations at range 70, the 9 m stations at Ranges 71, 72, 73, 74 and both the 2 m and 9 m stations at Range 76.

The laboratory grain size information would not distinguish between bits of clay till which were probably included in some of the hard bottom mid channel stations and loose clay particles associated with the "ooze" sediments. The latter would be much more likely to have elevated contaminant levels since they represent recent sediments and have a higher available surface area for adsorption than the till.

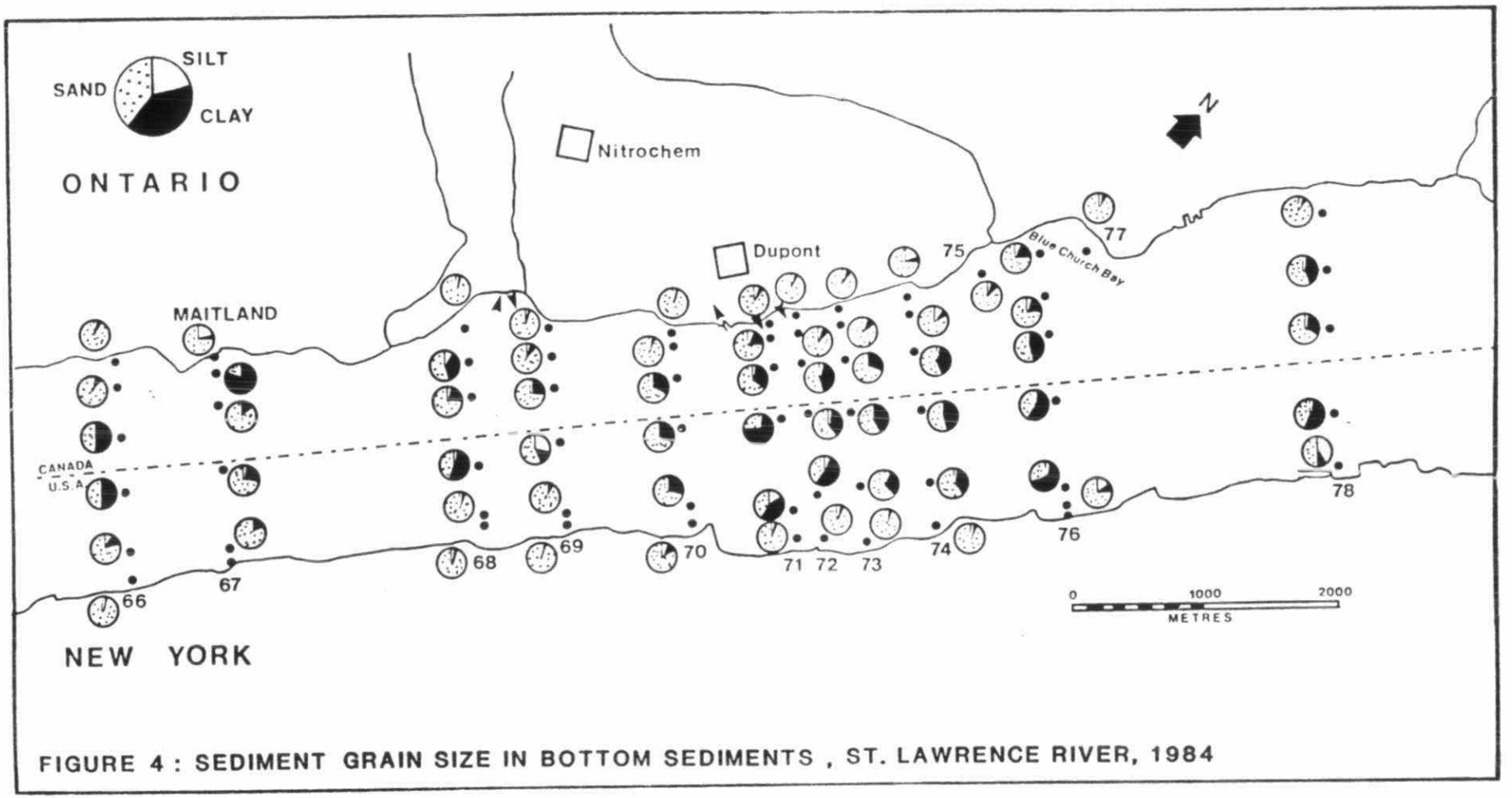


FIGURE 4 : SEDIMENT GRAIN SIZE IN BOTTOM SEDIMENTS , ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.
CONCENTRATION CONTOURS INTERPOLATED MANUALLY BY W. D. WILKINS & ASSOC.

5.2 Sediment Chemistry

The sediment chemistry is plotted in figures 5 through 17. Each figure indicates the MOE guideline for acceptable open water disposal of dredge spoils (where available)--one measure of sediment quality (Persaud and Wilkins, 1976). Downstream of range 78 the sampling stations were too far apart to be included in the contouring of results. The results were all within the range of the fully described values and are included in the appendices.

Two distinct patterns emerge in the results. One group of parameters (including TKN, Solvent extractables, Pb, Hg and TOC) closely corresponds with the sediments described as "ooze." The other grouping (which includes Total P, Fe, As and Co) has its highest values at the deep-water mid-river stations. The parameters Loss on Ignition, Zn, Cr and Cu share both patterns having their highest values in the "ooze" area but otherwise showing a pattern of increasing values with depth.

The two predominant patterns are modified by the influence of the Dupont outfalls for only a few parameters and not at all by the Nitrochem outfall. A plume of elevated Pb levels extends at least 3 km downstream of the Dupont outfalls. A calculation of the amount of lead within the defined plume (assume a sediment dry density of 1,800 kg/m3 and a 10 cm thick contaminated layer) yields 4,365 kg or about 1% of the estimated plant losses since it began operation. Oil and grease shows an increase for less than a kilometer as does copper. Cobalt appears slightly elevated at the outfall. Total Kjeldahl nitrogen just downstream of Dupont's outfalls may be slightly elevated.

Over the study area, 39 of the 74 stations had one or more parameters which exceeded the MOE dredge spoil guidelines.

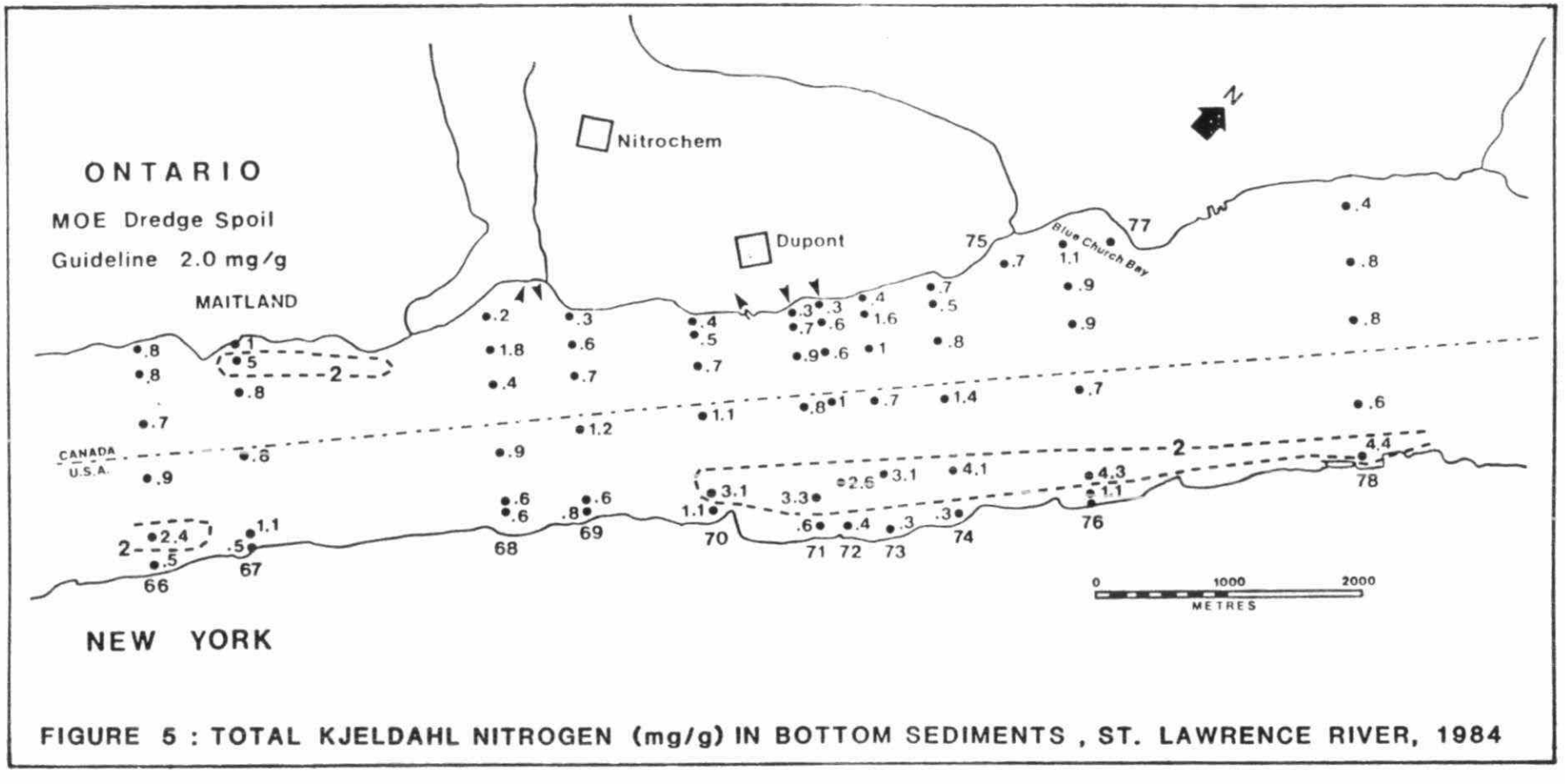


FIGURE 5 : TOTAL KJELDAHL NITROGEN (mg/g) IN BOTTOM SEDIMENTS , ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.
CONCENTRATION CONTOURS INTERPOLATED MANUALLY BY W. D. WILKINS & ASSOC.

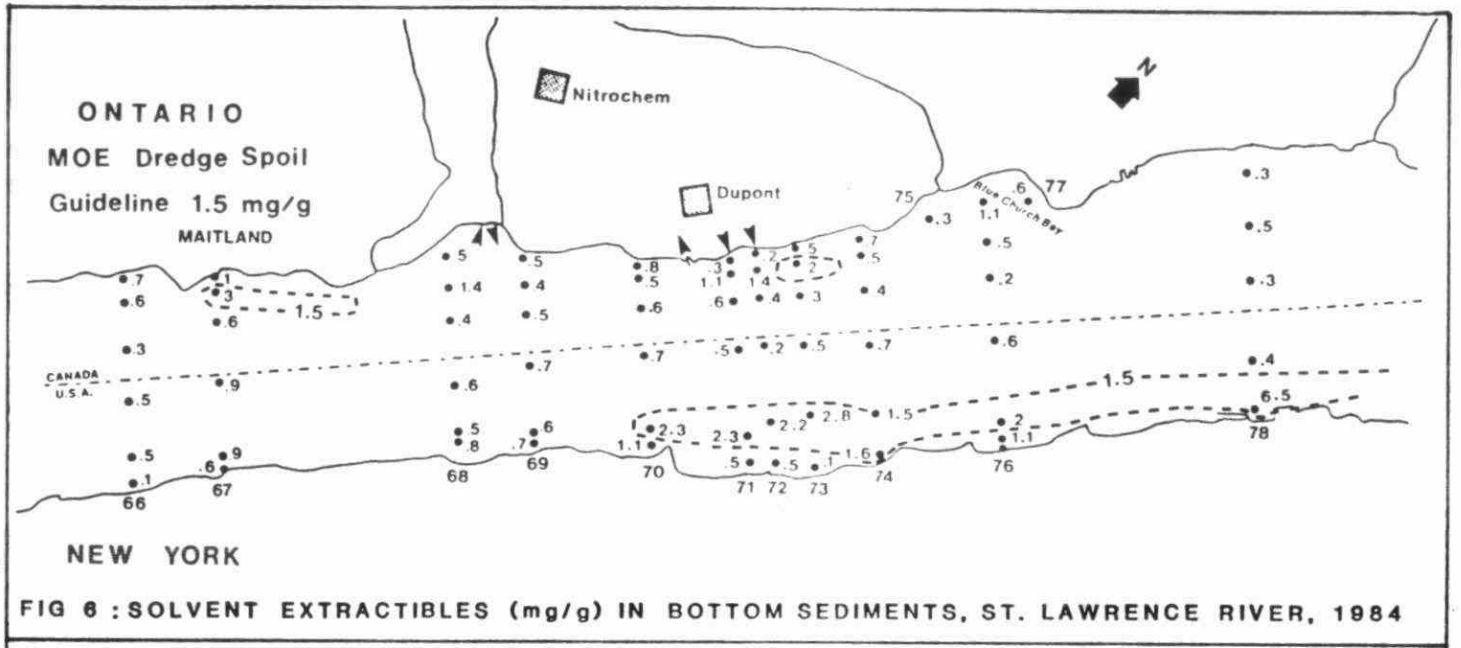


FIG 6 : SOLVENT EXTRACTIBLES (mg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

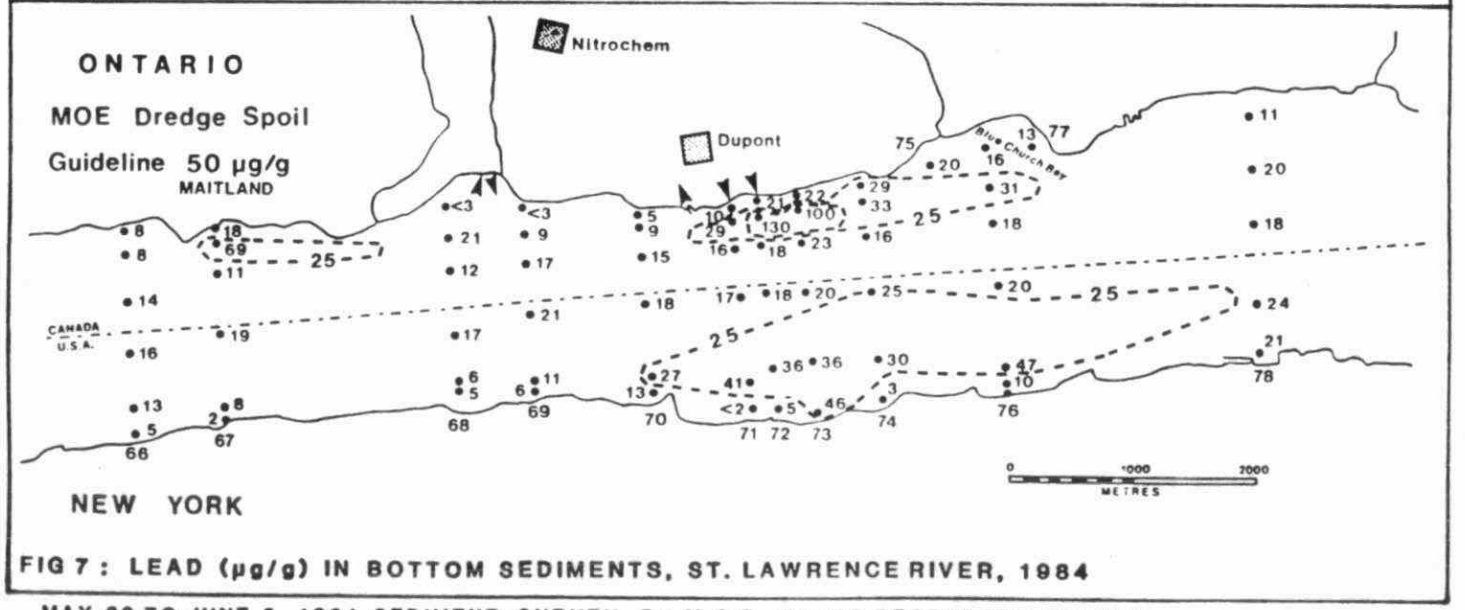


FIG 7 : LEAD (µg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.
CONCENTRATION CONTOURS INTERPOLATED MANUALLY BY W. D. WILKINS & ASSOC.

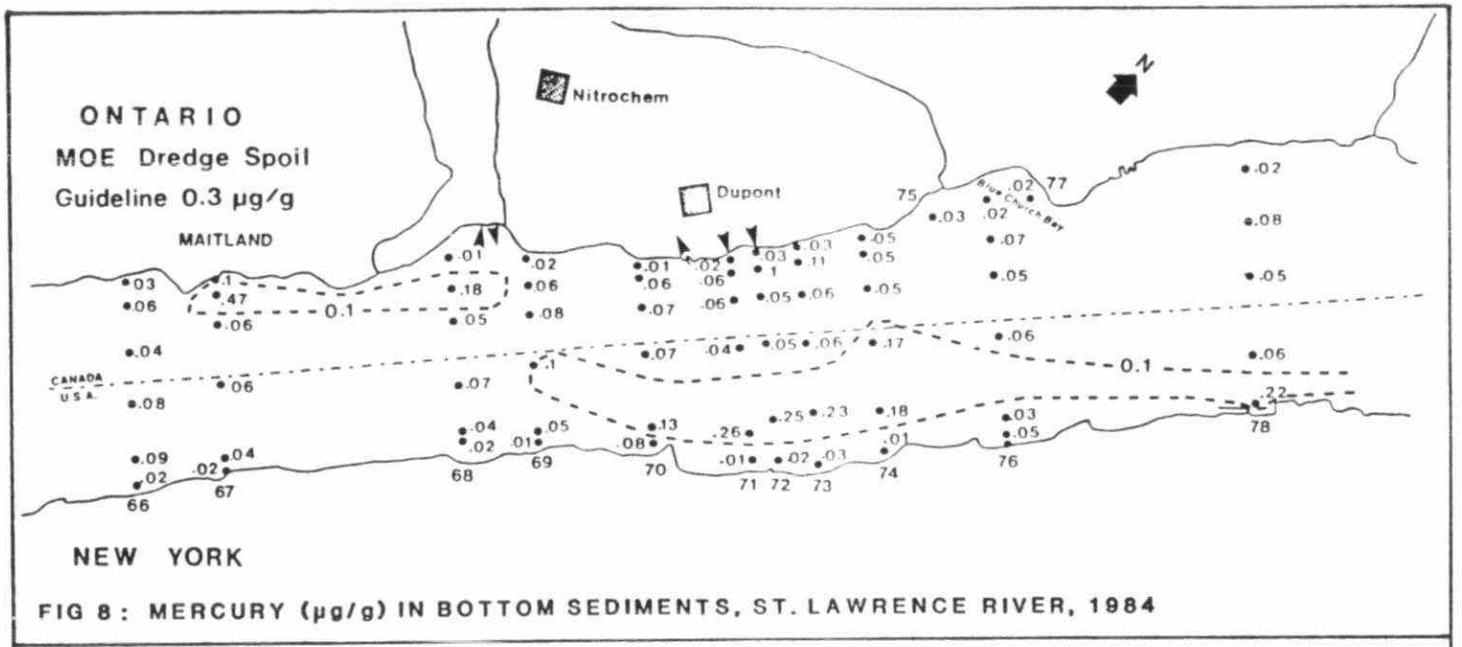


FIG 8 : MERCURY (µg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

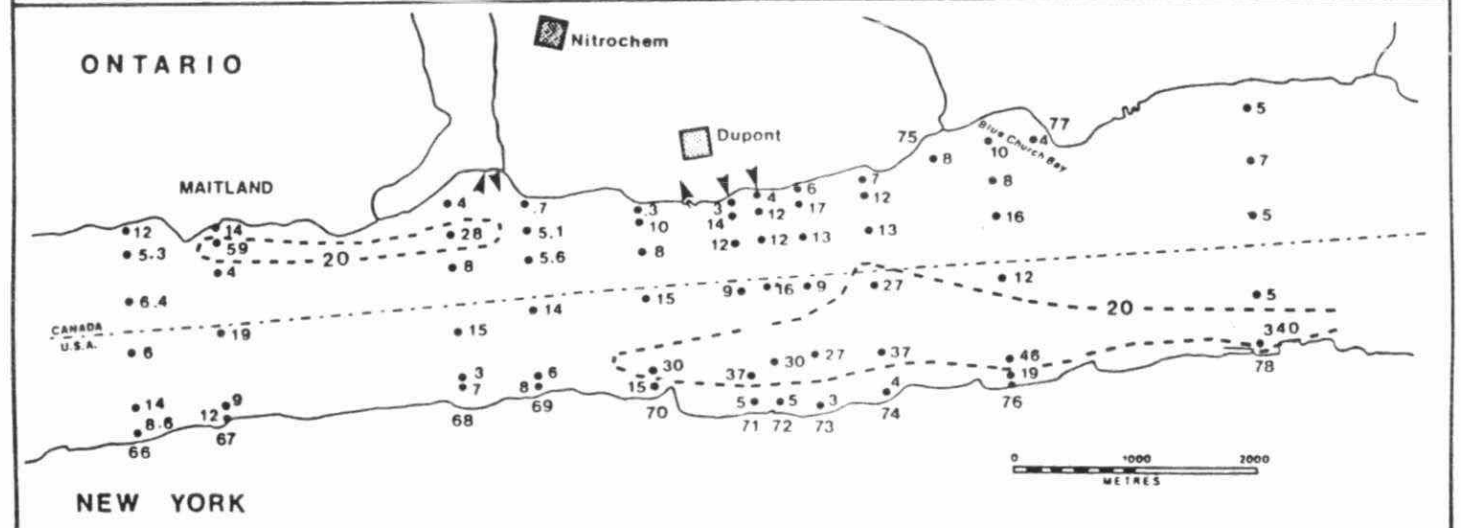


FIG 9 : TOTAL ORGANIC CARBON (mg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.
CONCENTRATION CONTOURS INTERPOLATED MANUALLY BY W. D. WILKINS & ASSOC.

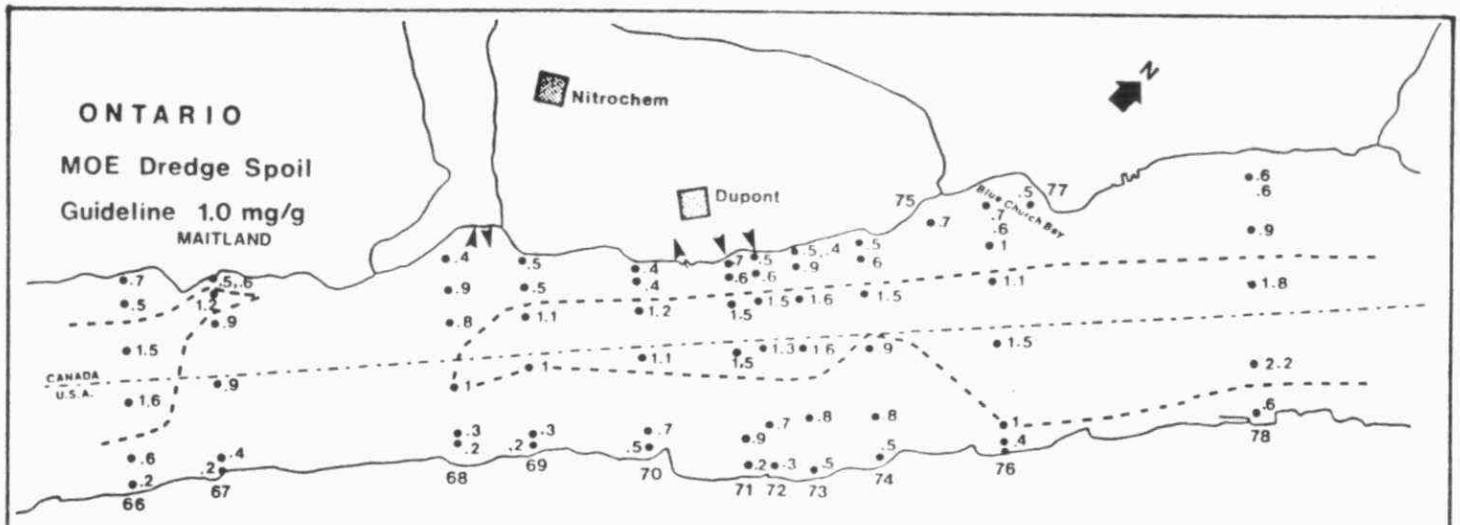


FIG 10 : TOTAL PHOSPHORUS (mg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

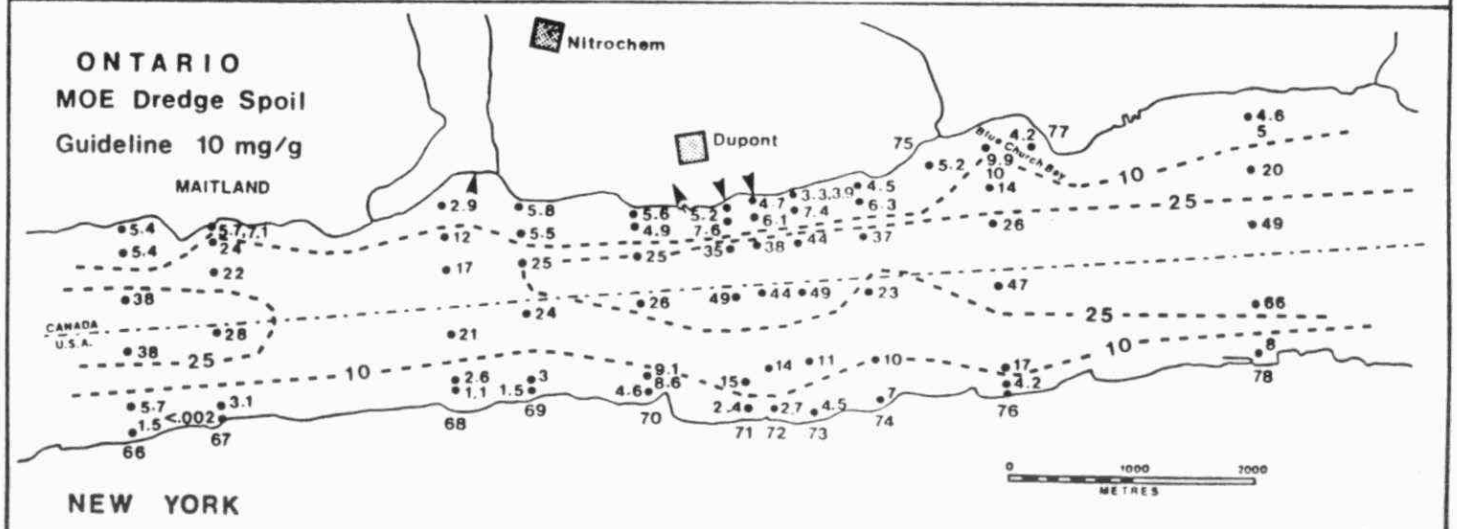


FIG 11 : IRON (mg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.
CONCENTRATION CONTOURS INTERPOLATED MANUALLY BY W. D. WILKINS & ASSOC.

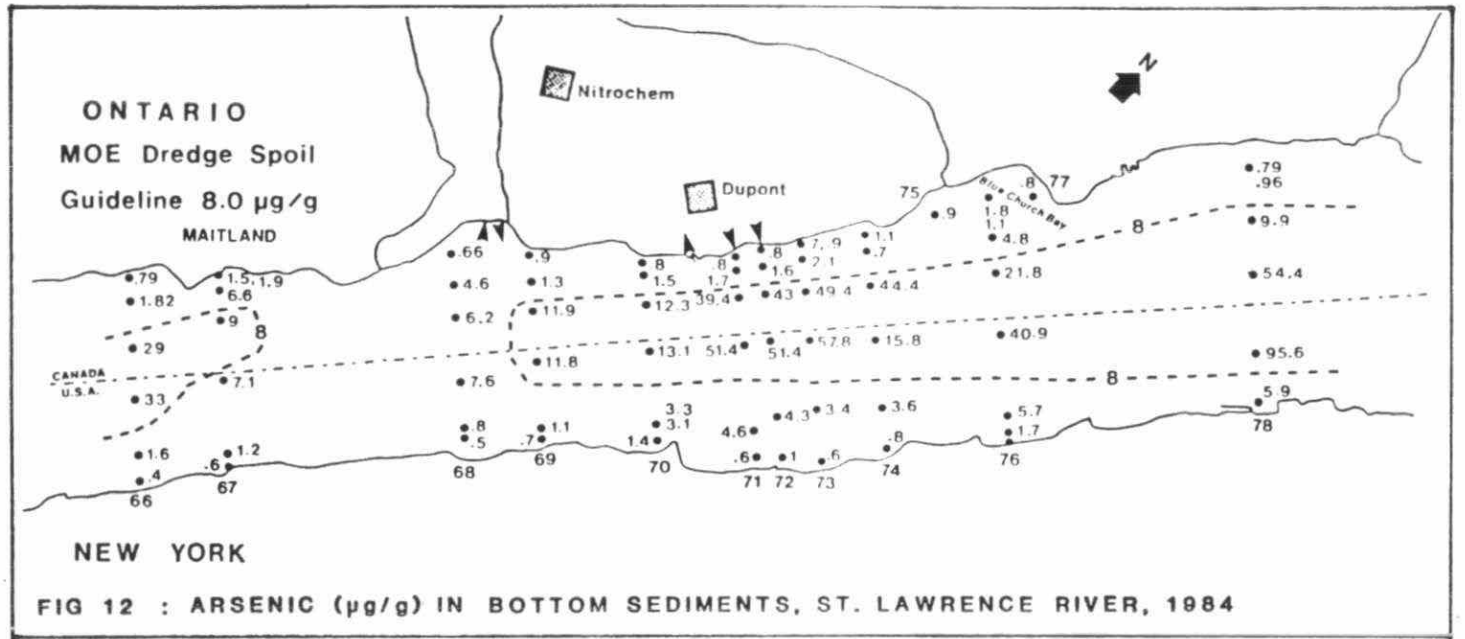


FIG 12 : ARSENIC (µg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

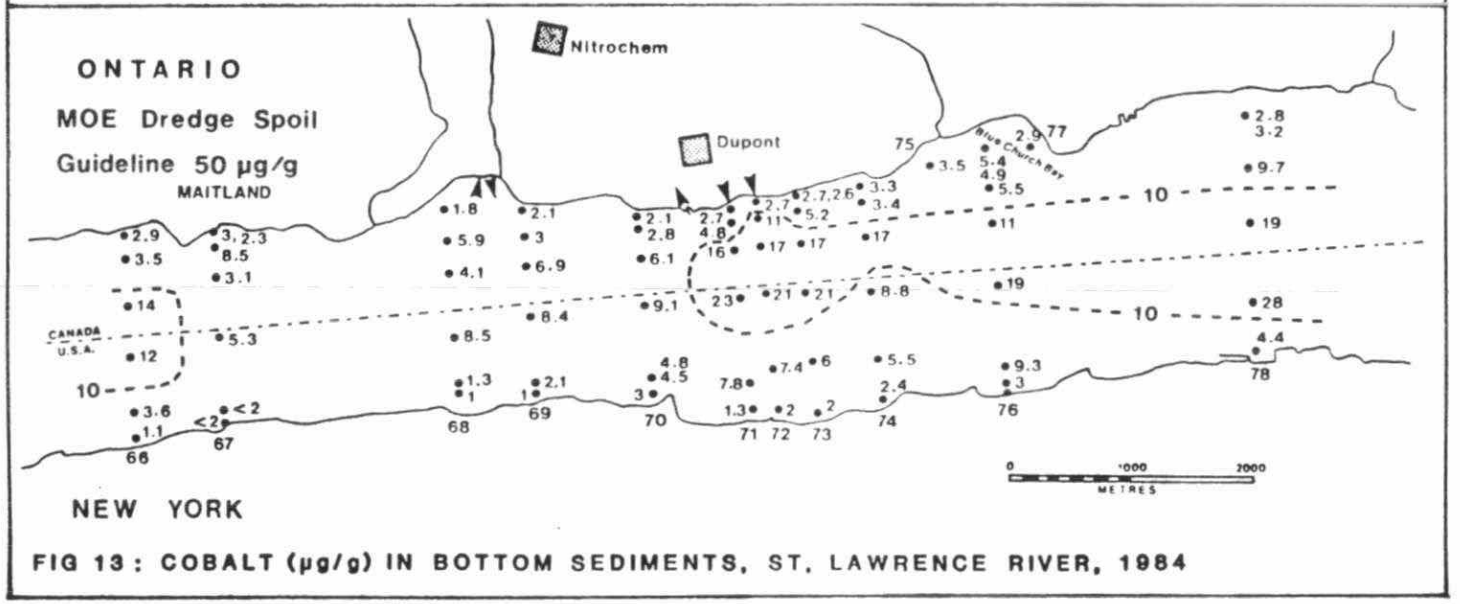


FIG 13 : COBALT (µg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.
CONCENTRATION CONTOURS INTERPOLATED MANUALLY BY W. D. WILKINS & ASSOC.

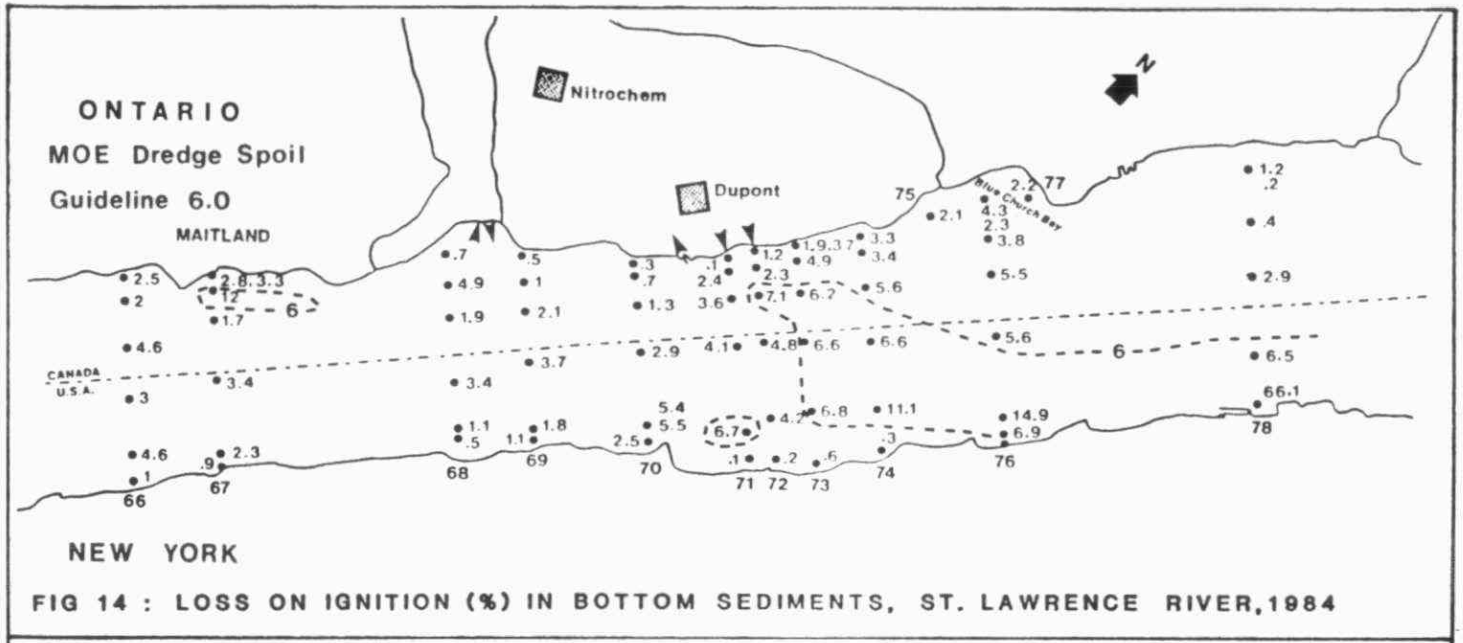


FIG 14 : LOSS ON IGNITION (%) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

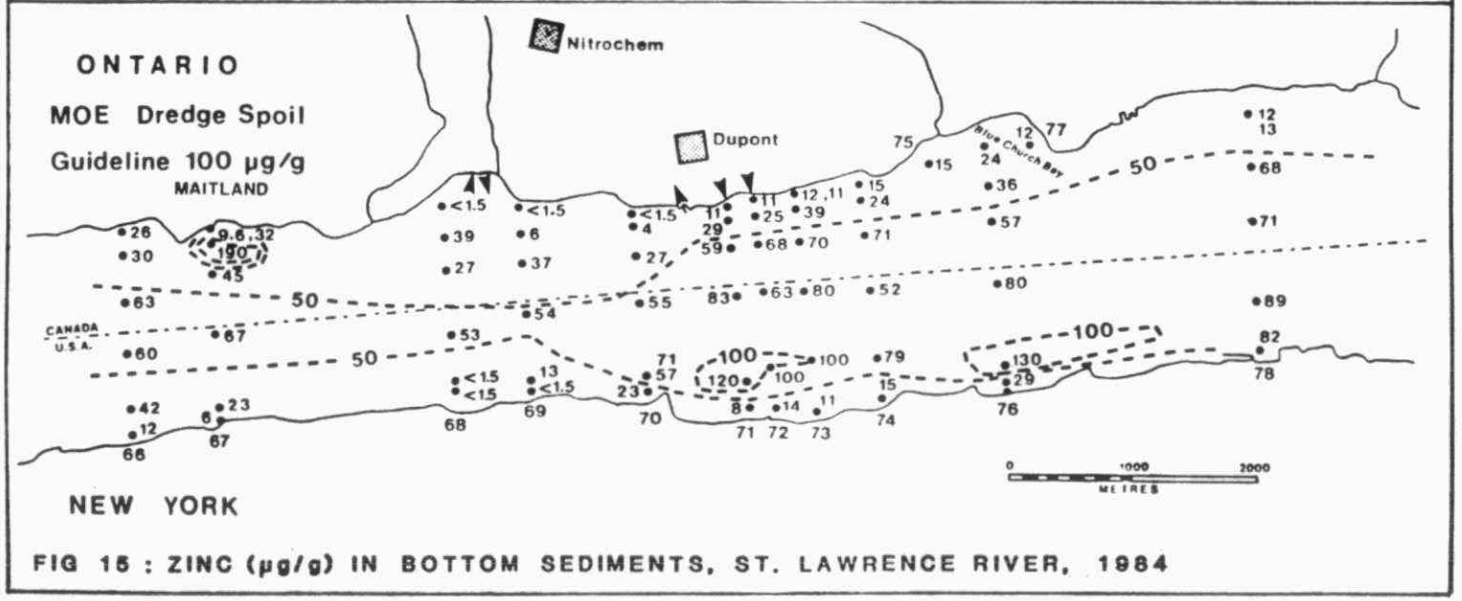


FIG 15 : ZINC (µg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.
CONCENTRATION CONTOURS INTERPOLATED MANUALLY BY W. D. WILKINS & ASSOC.

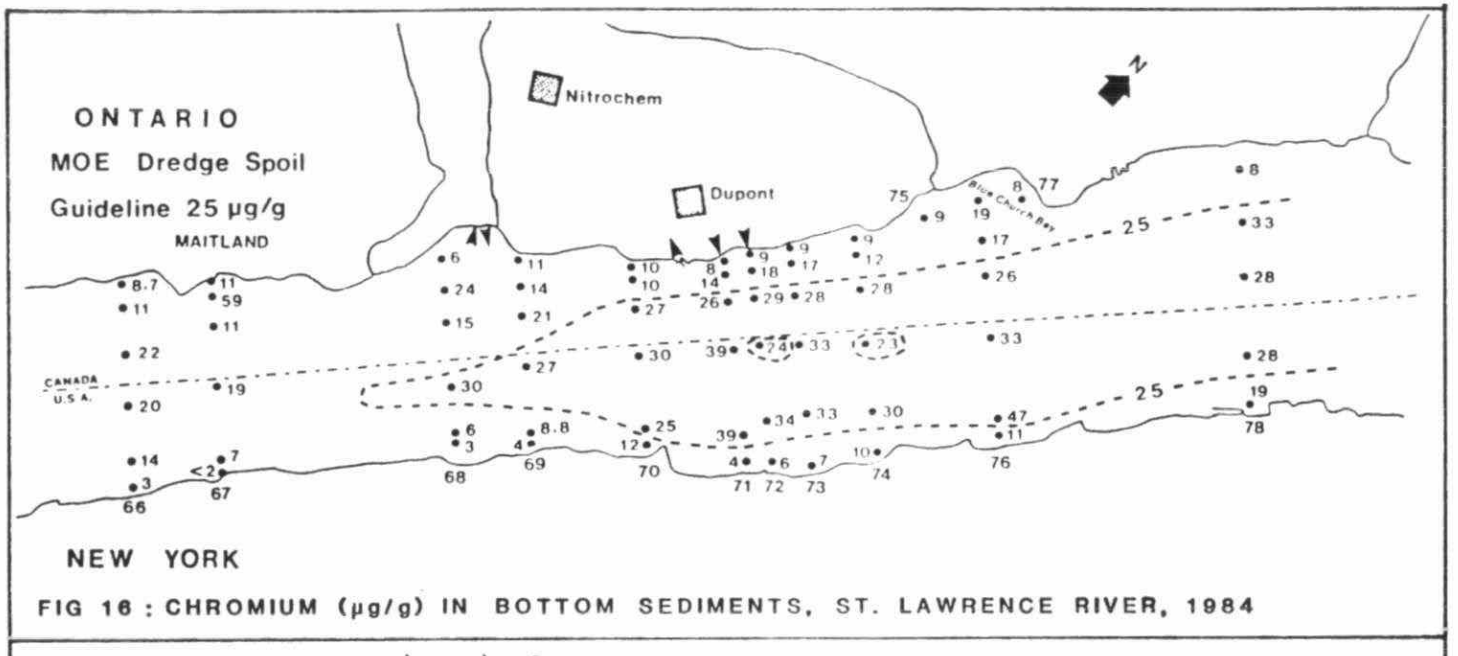


FIG 16 : CHROMIUM (µg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

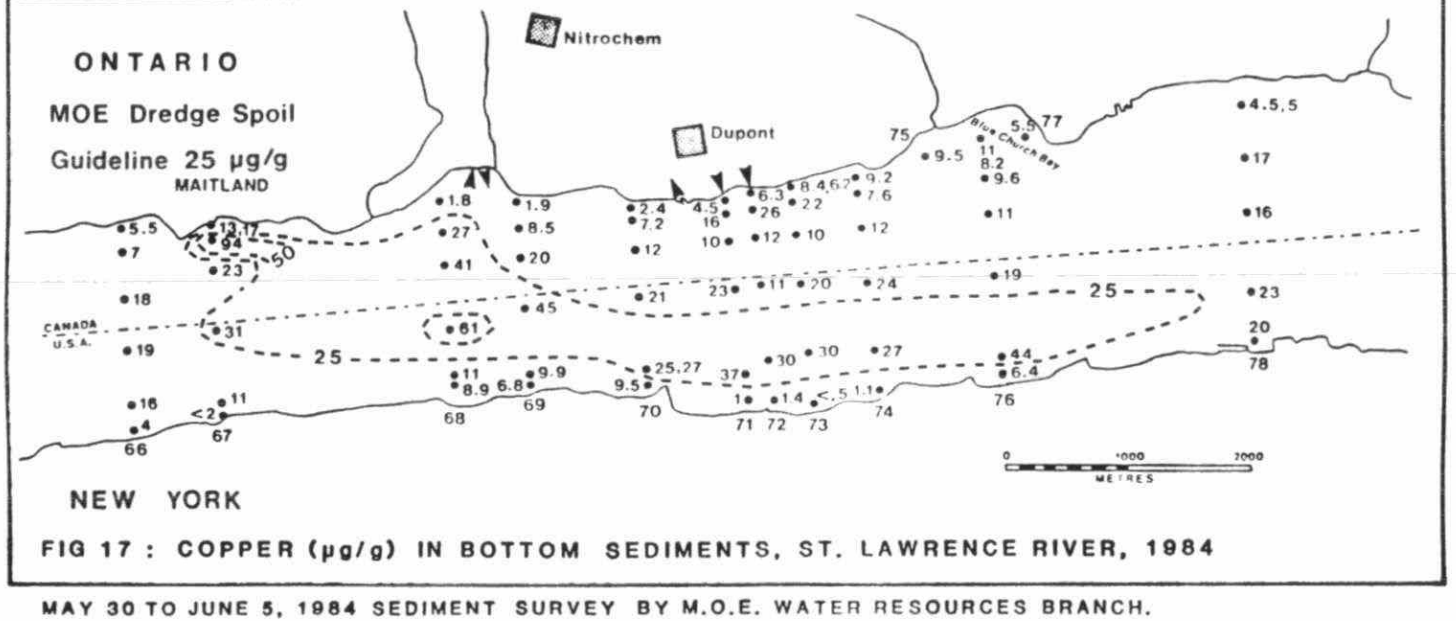


FIG 17 : COPPER (µg/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.
CONCENTRATION CONTOURS INTERPOLATED MANUALLY BY W. D. WILKINS & ASSOC.

5.3 Sediment Trace Organics

Samples were analysed for PCBs, HCB (hexachlorobenzene),heptachlor, aldrin, mirex, pp DDE, dieldrin, endrin, alpha, beta and gamma BHC, alpha and gamma chlordane, oxychlordane, opDDT, ppDDT, pp DDD, DMDT (methoxychlor), heptachlor epoxide, endosulphan I, II and sulphate. The following were not detected in any samples and thus do not appear in the Appendix C tabulation of the data; heptachlor, heptachlor epoxide, aldrin, mirex, beta and gamma BHC, alpha chlordane, opDDT, ppDDT and endosulphan II. PCBs, HCBs, pp DDE and dieldrin are plotted in figures 18 to 21. Although the data points are too sparse to permit contouring, the "ooze" areas show some of the highest levels of contamination.

PCBs do appear elevated below the Dupont outfalls; however, levels upstream at the same depth are more than twice as high, complicating any causal association.

HCBs are 2 orders of magnitude higher in the Dupont outfall zone than anywhere else in the survey area. The concentration declines rapidly with distance downstream and is within the range of upstream values by Blue Church Bay.

The distribution of DDE and dieldrin is consistent with a source upstream of the survey area and shows no influence by local outfalls.

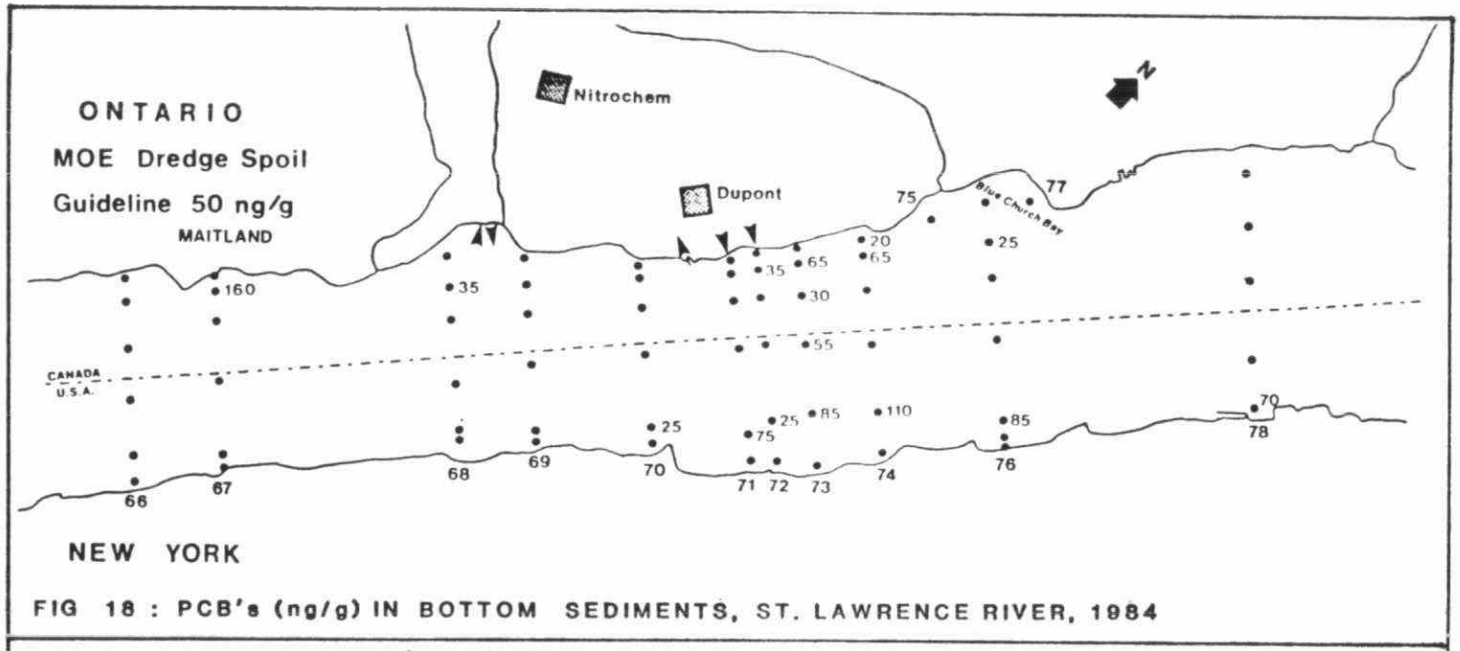


FIG 18 : PCB's (ng/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

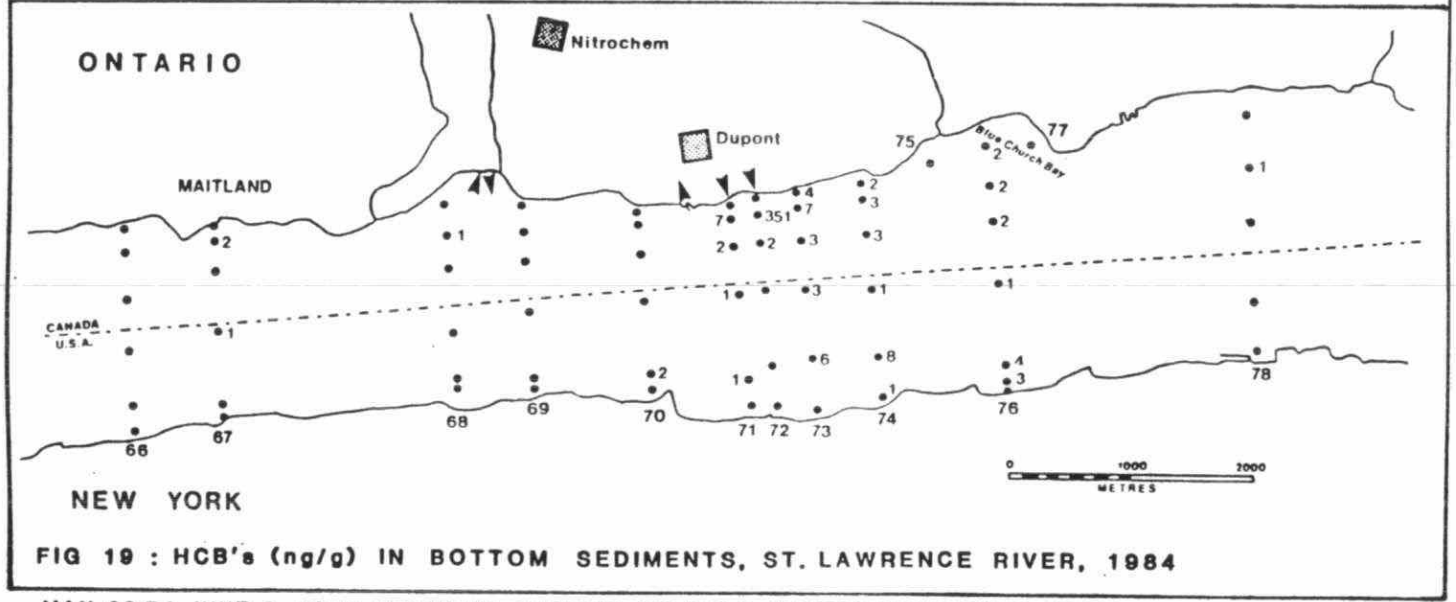


FIG 19 : HCB's (ng/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.

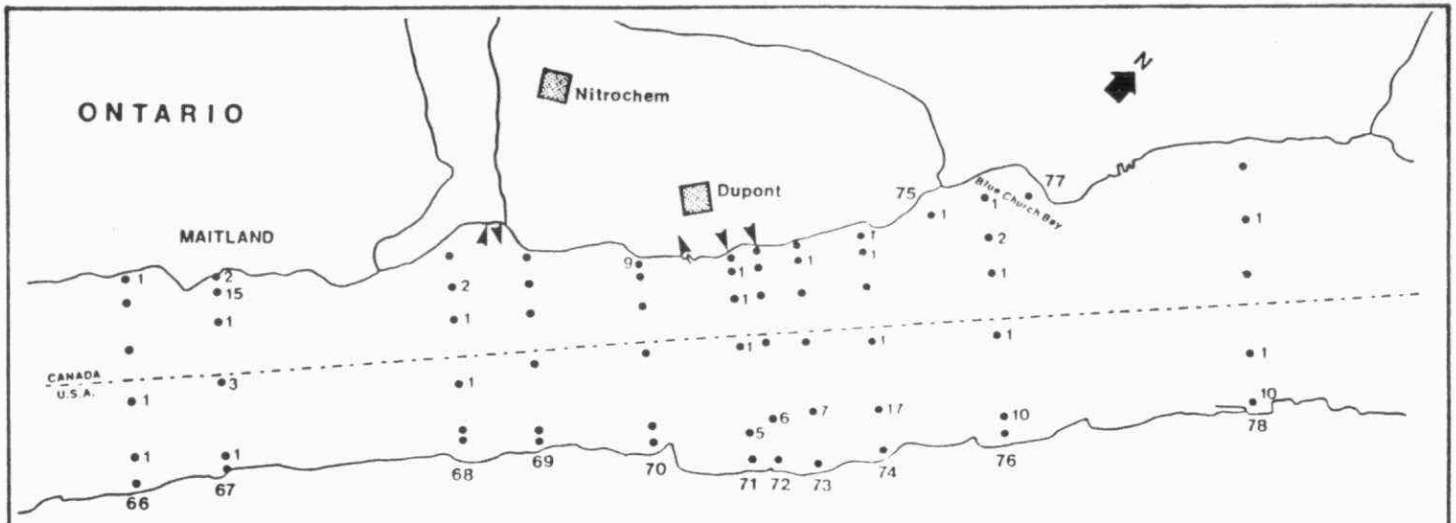


FIG 20 : DDE (ng/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

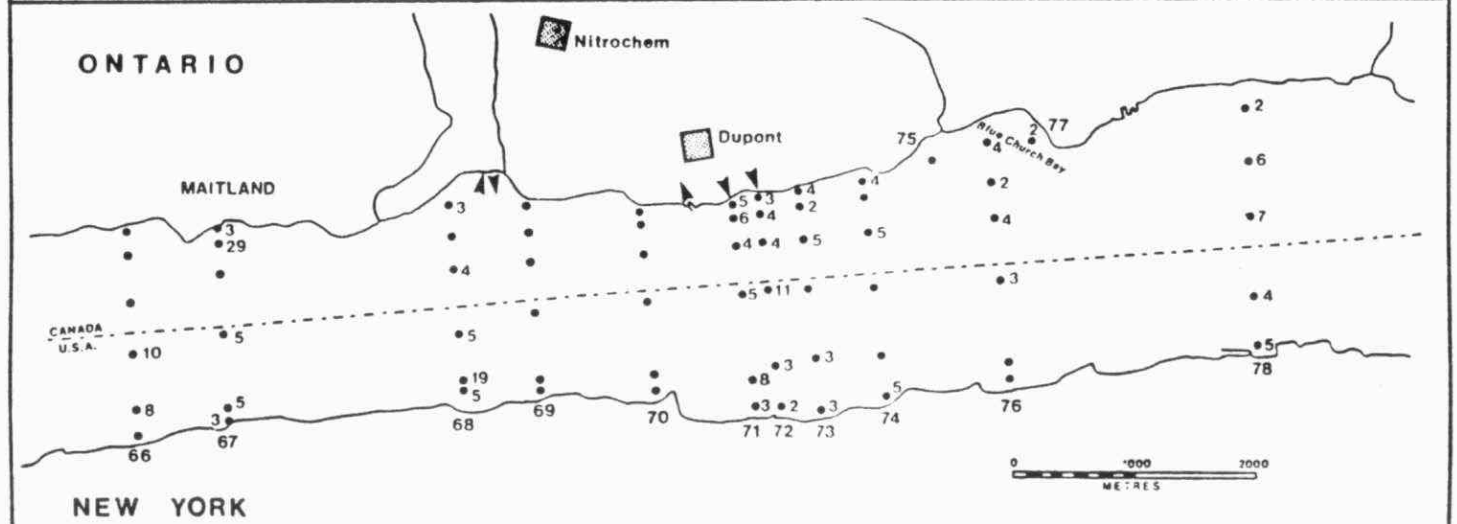


FIG 21 : DIELDRIN (ng/g) IN BOTTOM SEDIMENTS, ST. LAWRENCE RIVER, 1984

MAY 30 TO JUNE 5, 1984 SEDIMENT SURVEY BY M.O.E. WATER RESOURCES BRANCH.

6. DISCUSSION

6.1 Comparison with 1975

The availability in 1984 of a better set of control stations upstream and across the river from the limited study area of 1975 provides a different interpretation of the earlier data. In the 1984 data there is no discernible impact from the Nitrochem (Genstar) outfall in terms of nutrients, organic content, heavy metals or trace organic chemicals.

Instead, a zone of contaminated sediments is observed upstream of the Nitrochem outfall in Claybank Bay and Maitland Bay. This zone has a high organic content (up to 12% LOI, 59 mg/g TOC), high nutrient levels (up to 5.0 mg/g TKN and 1.2 mg/g Total P), elevated heavy metal levels (Pb, Hg, Zn, Cr, Cu), and high trace organic contaminant levels (PCB's, pp DDE,pp DDD, dieldrin and endrin). There are no known discharges in the immediate Maitland vicinity to account for such high contaminant levels.

The Dupont outfalls show only a limited impact in terms of sediment quality. The most obvious parameter affected is lead. In 1984 a discernible plume extended from the outfall downstream past Blue Church Bay (a distance in excess of 3 km) very much like the 1975 lead plume. The maximum lead value in the May/June survey of 1984 was 130 mg/kg compared to 190 mg/kg in 1975. In 1984 the impact of the Dupont outfalls on the sediment levels of Cu, Co and TKN is small and localized with influences outside of the 1975 survey area accounting for the highest values. For Fe, Zn, Loss on Ignition and Total P there was no impact associated with the outfalls. Absolute values for these parameters were in the same range in 1984 as that observed in 1975 but the distribution pattern in the 1984 data clarified the dominant role of transport from an upstream source. Trace organic contaminants were not examined in 1975. Errors and omissions in the 1975 data base and the limited number of common stations in the 1975 and 1984 surveys precluded useful statistical manipulations of the data.

6.2 Short-Term Temporal and Spatial Variability

The seventy-four station sediment survey was undertaken between May 30 and June 5, 1984. Of the seventy-four stations duplicate samples were collected at six. Table 1 shows some typical results for the duplicate samples and the number of Shipek grabs required to collect sufficient sample. Although none of the samples were located in areas deemed contaminated it would appear that the sampling effort was adequate to obtain representative samples.

TABLE 1. DUPLICATE SAMPLE CONCENTRATIONS AND SAMPLING EFFORT

Station	Pb (ug/g)	Fe (ug/g)	%LOI	No. of grabs
67 (2m)	23; 14	5,700; 7,100	2.8; 3.3	6;6
70 (9m)	27; 27	9,100; 8,600	15.4; 5.3	4;4
73 (2m)	25; 20	3,300; 3,900	1.9; 3.7	8;4
76 (2m)	13; 18	9,900;10,000	4.3; 2.5	3;3
78 (2m)	9.9; 12	4,600; 5,000	1.2; 0.2	3;3
81 (2m)	7.3; 5.9	7,300; 9,600	0.3; 1.4	3;3

Through part of a caged fish lead uptake study (Flood, 1986) more sediment samples were collected on August 17 and September 5, 1984, 500 m upstream and 150 m downstream of the Dupont outfall and in Blue Church Bay. At the upstream (control) stations and the discharge stations water depth at the cages varied from 6.1 m (north) to 6.7 m (south). In Blue Church Bay cages were at 3.4 m to 4.0 m depths. Each sample value shown in Table 2 represents the analysis of a single Eckman grab sample taken 10 m to the south, east, and north of the caged fish. Three replicate grabs were collected at the discharge location.

TABLE 2 - Sediment Lead Concentrations at Fish Cage Sites, 1984

August 17	10m South	10m East	10m North
Control	13	13	28
Discharge i	166	249	286
ii)	58	163	160
iii)	129	279	223
Blue Church Bay	177	150	108
September 6			
Control	11	10	17
Discharge i)	86	842	268
ii)	108	797	202
iii)	125	340	375
Blue Church Bay	111	125	184

TABLE 3 - Sediment Lead Concentrations
May to September 1984 and in 1975
lead concentrations in ug/g ± 1 S.D.

	May, June 1984	August 17 1984	September 6 1984	1975
control	9	18 ± 8.7	13 ± 3.8	14
discharge	130	230 ±60.2	660 ±277.8	190
Blue Church Bay	25	145 ±34.8	140 ± 38.7	13

An examination of the mixing zone data in Figures 22 & 23 (Hamdy, MOE, unpublished) indicates that the tetra ethyl lead plant plume is only about 16 m wide 150 m downstream of the discharge point. This suggests that samples taken 10 m south and north of the discharge could be outside of the main plume. The Table 2 data supports this since the mean value in the south discharge samples is half or less the east (downstream centerline) samples. For comparison with the May, June survey (one analysis of 3 or more Shipek grabs) the three Eckman values are combined for the control and for Blue Church Bay and the three east (most representative of the plume) samples are used for the discharge. Concentrations for May, June are estimated from the contours in Figure 7. Concentrations for 1975 are estimated from the contours in the 1978 report on those results. The results are combined in Table 3.

The values shown in Table 2 for the discharge samples show the extreme variability in three replicate samples as well as the difference between groups of samples 10 to 20 m apart.

Table 3 indicates that sediment lead levels at the discharge increased between May and August 17 and increased sharply again by September 6. At Blue Church Bay there was an increase between May and August 17 but the September 6 increase at the discharge was not yet evident downstream. The September 6, 1984 discharge samples and Blue Church Bay samples for August 17 and September 6 were also substantially higher than reported in 1975.

For an explanation of the temporal variations and examination was made of the daily lead output from the TEL plant. Figure 24 plots the daily lead loadings for the period before the May/June survey (June 4/84 for stations near the outfall) and for August 11 to September 6, 1984. The data are typical of the plant's output according to the 1983 and 1984 data available. Lead concentrations in the sediment are compared with the TEL plant loading for 1,3,5 and 10 days prior to the three 1984 surveys in Table 4. At the discharge station the sediment concentration correlates most

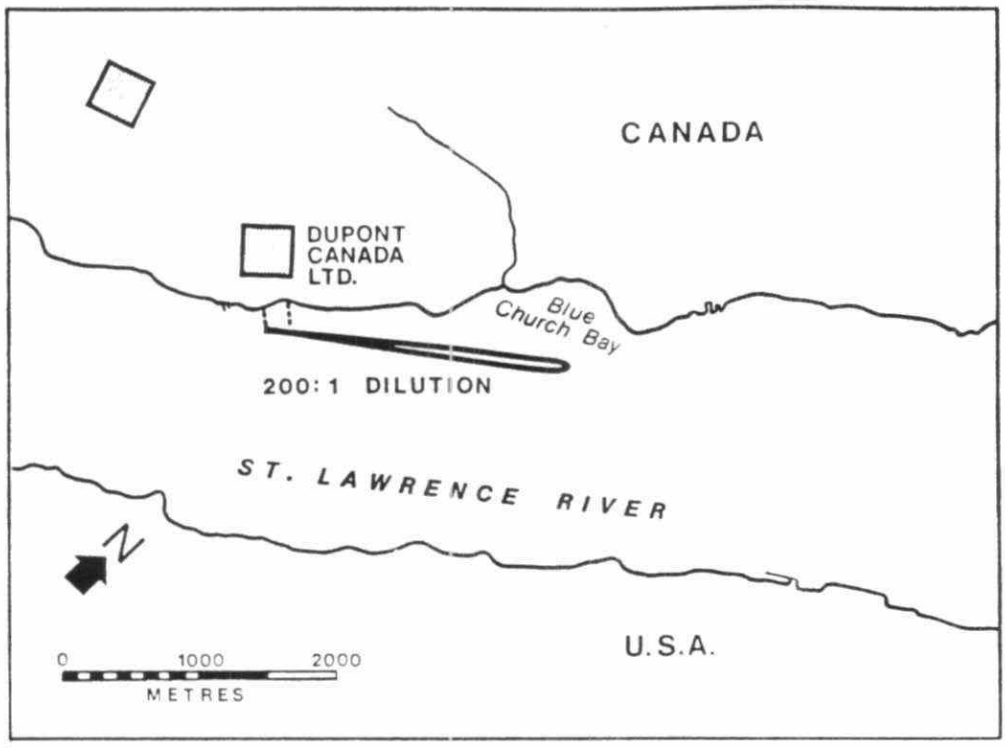


FIGURE 22 : TEL- PB MIXING ZONE

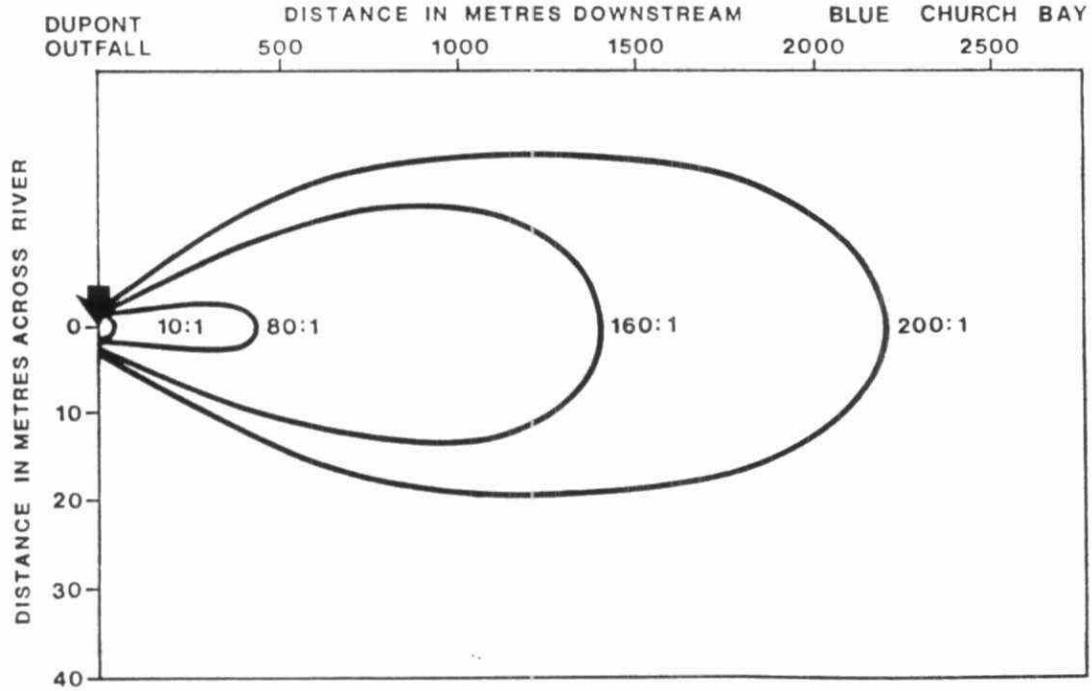


FIGURE 23 : TEL - PB MIXING ZONE

Y. Hamdy, M.O.E., unpublished

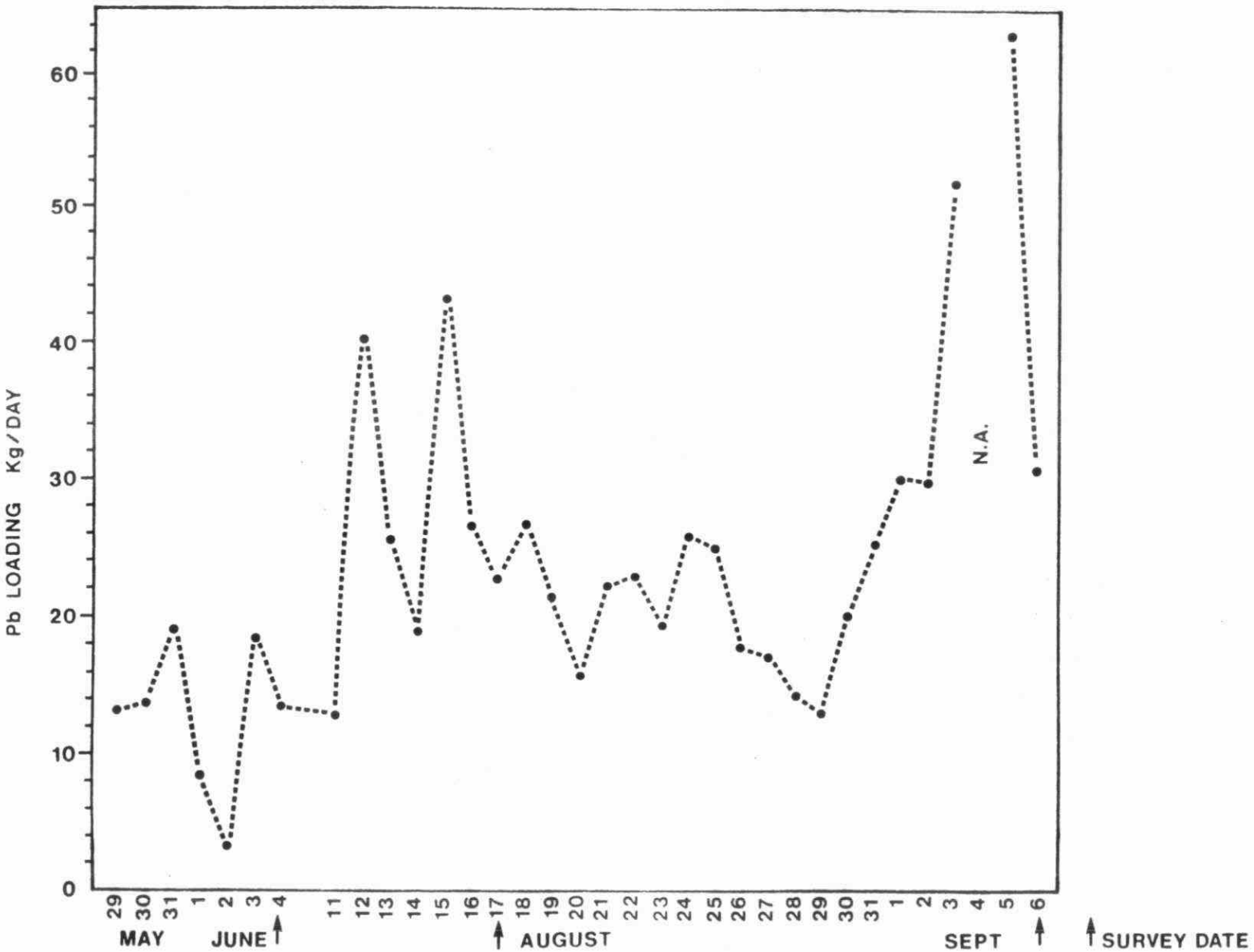


FIGURE 24 : TEL PLANT EFFLUENT LEAD LOADING (KG/DAY)

closely with the previous day's loading. Two kilometres downstream at Blue Church Bay the sediment levels reflect a longer discharge history and the relationship with plant output is less distinct. Loading fluctuations over the period of the three 1984 surveys were sufficient to explain the observed variations in sediment lead levels.

TABLE 4 - Sediment Concentrations and Effluent Loadings

	June 4	Aug. 17	Sept. 6
Discharge sediment conc. (ug/g)	130	230	660
previous day's loading (kg/day)	18.3	26.4	63.1
mean loading for 3 previous days	10.0	29.5	57.3*
mean loading for 5 previous days	12.6	30.9	43.6*
mean loading for 10 previous days	14.2	27.2	29.4*
Blue Church Bay sediment conc. (ug/g)	25	145	140

* mean of n-1 days September 4 data not available

6.3 Regional Variability

The sediment contaminant distribution indicates a source for all parameters upstream of the 1984 study area. To place the levels measured in 1984 in a regional context references were sought which provided data for upstream areas of the St. Lawrence River and for Eastern Lake Ontario. Environment Canada sampled St. Lawrence River sediments from Lake Ontario to Lake St. Francis in June 1975. The results are reported in a May 6, 1985 report by K.W. Kuntz. A USBM-54 sampler which collects the top 2.5 cm of sediment was used at the locations from the Kingston area to the Cornwall area. Results for lead, copper, iron and arsenic are shown in Figures 25-28.

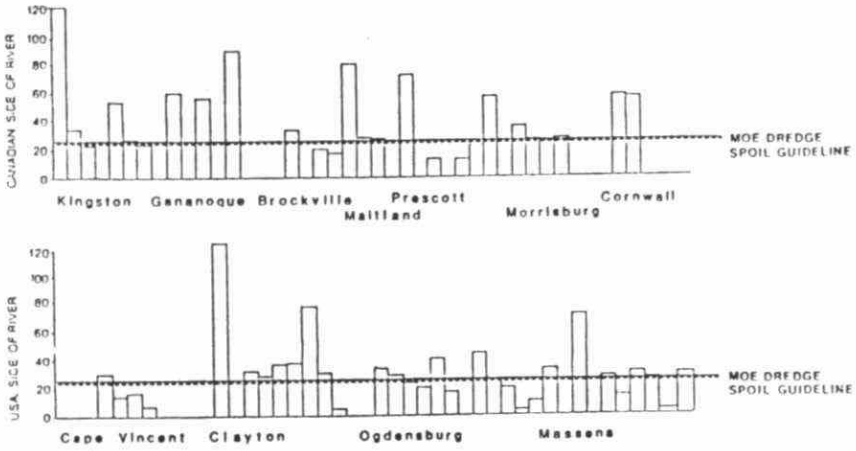

CANADIAN SIDE OF RIVER
MOE DREDGE SPOIL GUIDELINE
Kingston Gananoque Brockville Prescott Maitland Morrisburg Cornwall
USA SIDE OF RIVER
MOE DREDGE SPOIL GUIDELINE
Cape Vincent Clayton Ogdensburg Massena

Fig. 25: COPPER ($\mu g.g^{-1}$) IN BOTTOM SEDIMENTS OF THE ST.LAWRENCE RIVER IN 1975

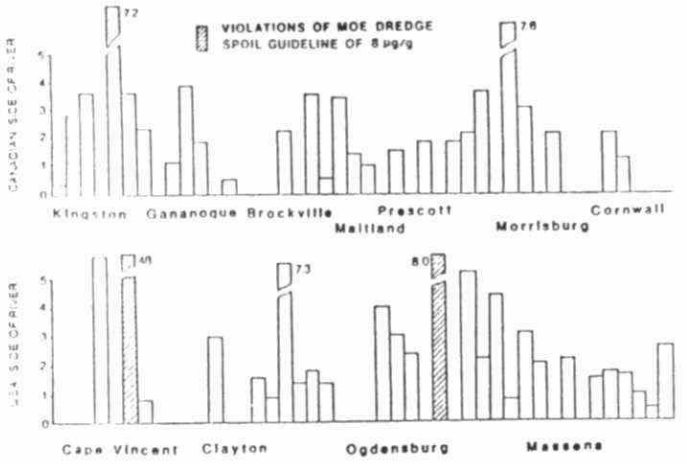


Figure 26: ARSENIC ($\mu g.g^{-1}$) IN BOTTOM SEDIMENTS OF THE ST.LAWRENCE RIVER IN 1975

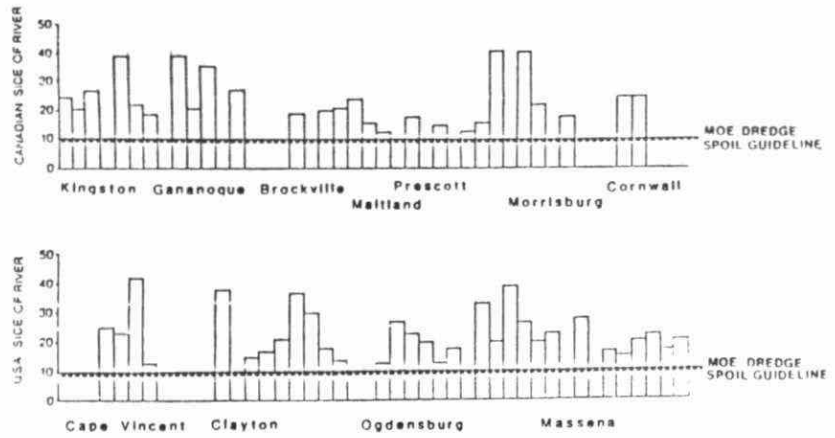
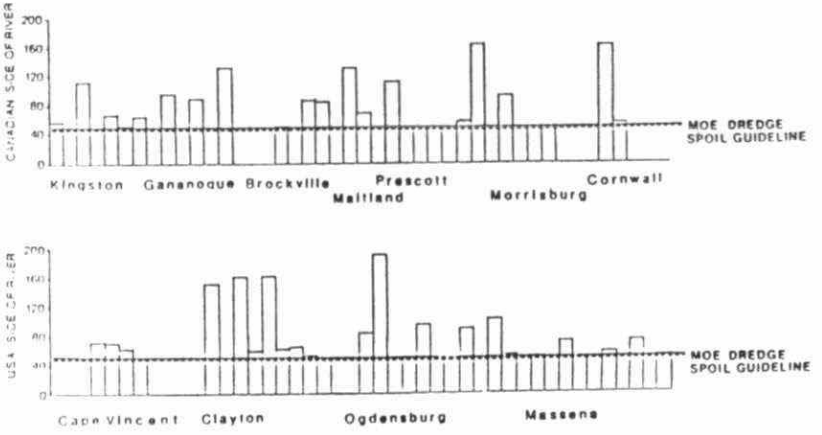

CANADIAN SIDE OF RIVER
MOE DREDGE SPOIL GUIDELINE
Kingston Gananoque Brockville Prescott Maitland Morrisburg Cornwall
USA SIDE OF RIVER
MOE DREDGE SPOIL GUIDELINE
Cape Vincent Clayton Ogdensburg Massena

Figure 27: IRON ($mg.g^{-1}$) IN BOTTOM SEDIMENTS OF THE ST.LAWRENCE RIVER IN 1975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MOE DREDGE SPOIL GUIDELINE
Kingston Gananoque Brockville Prescott Maitland Morrisburg Cornwall
USA SIDE OF RIVER
MOE DREDGE SPOIL GUIDELINE
Cape Vincent Clayton Ogdensburg Massena

Figure 28: LEAD ($\mu g.g^{-1}$) IN BOTTOM SEDIMENTS OF THE ST.LAWRENCE RIVER IN 1975

ref. Kuntz, 1985

Violations of the MOE sediment guidelines were frequent throughout the length of the river. Environment Canada values 0.5 km above and below the Dupont outfalls were within the range reported by MOE for 1975. Environment Canada reported higher values for most parameters at the upstream station. Few of the reported violations could be adequately accounted for by local sources. Sediment lead concentrations near a major source of lead like the Dupont plant (approx. 54 kg Pb/day in 1975) were equalled or exceeded at several sites with no known sources of lead. This pattern was repeated for most if not all parameters.

In 1981 J.O. Nriagu, H.K.T. Wong and R.D. Coker of the National Water Research Institute reported the results of chemical analyses of suspended and surface sediments collected from Lake Ontario in 1978. Table 5 provides a summary of the results for the easternmost basin in Lake Ontario and the sample collected at Range 67 (depth 9 m) during the May, June 1984 MOE St. Lawrence survey. The suspended particulates had a higher organic content but similar trace metal composition to the surficial sediments. Lake Ontario samples were higher for all parameters tested (except iron) than the St. Lawrence River station although the latter had some of the highest contaminant levels observed in the 1984 survey.

MOE contracted a sediment survey of nearshore Lake Ontario in 1981. The results for three stations in eastern Lake Ontario are compared with two St. Lawrence River stations from 1984 in Table 6. The Lake Ontario stations are from a 20 m depth. At the Ostrander Point and False Duck Islands stations the 20 m depth probably represents a transport zone rather than a depositional zone. There are no point sources of contaminants in the area.

The St. Lawrence River values (high values from the 1984 survey) are generally intermediate between the Ostrander Point/False Duck Islands values and the higher values associated with a depositional basin in Prince Edward Bay.

TABLE 5 - Contaminant Levels in Suspended Particulate in Lake Ontario Compared to Lake Ontario and St. Lawrence River Sediments (results in ug/g)

Parameter	Suspended Particulate in Kingston Basin*	Surficial Sediment in Kingston Basin (top 1 cm)*	St. Lawrence River Range 67(9 m depth) (top 3 cm)
Pb	120	170	69
Fe	8,400 to 20,190	-	24,000
Zn	410 to 460	420	190
Cu	130 to 230	90	84
Ni	44 to 49	82	30
Cd	9	4.9	1.9
Organic C	16.6% to 30.6%	6.3%	5.9
Organic N	2.2% to 4.1%	-	-
Cr	-	120	59
Co	-	30	8.5

* from J.O. Nriagu, H.K.T Wong and R.D. Coker, 1981

TABLE 6 - Comparison of Sediment Quality at 3
Eastern Lake Ontario (1981) Stations
and 2 St. Lawrence River Stations (1984)

	Lake Ontario*			St. Lawrence River	
depth	Ostrander Pt. Range 22 20m	False Duck Islands Range 23 20m	Prince Edward Bay Range 24 20m	Range 67 9m	Range 71 9m south
LOI%	3.4	4.9	14	12	6.7
TKN mg/g	1.8	2.3	6.3	5.0	3.3
TP mg/g	0.88	0.93	1.3	1.2	0.9
Oil ug/g	1,510	925	1,900	3,060	2,330
Hg ug/g	0.12	0.18	.43	0.47	0.26
Pb ug/g	28	39	92	69	41
Zn ug/g	83	120	290	190	120
Fe ug/g	11,000	14,000	28,000	24,000	15,000
Cr ug/g	24	31	67	59	39
Cu ug/g	20	28	67	84	37
As ug/g	3.5	5.6	14	6.6	4.63
Cd ug/g	0.85	1.1	2.5	1.9	1.2
Ni ug/g	13	19	56	30	23
Co ug/g	3.6	4.4	13	8.5	7.8
PCB ng/g	188	76	240	160	75
HCB ng/g	3	3	8	2	1
pp DDE ng/	9	18	34	15	5
a chlordane ng/g	2	2	9	ND	ND
pp DDD ng/	ND	16	42	10	ND
dieldrin n/g	ND	3	5	29	8
endrin ng/	ND	21	29	100	45

* from Sediment Quality and Benthic Macroinvertebrates at 25 Transects in the Lake Ontario Nearshore Zone, 1981. by W.D. Wilkins.

BIBLIOGRAPHY

Allan, R.J., The Limnological Units of the Lower Great Lakes--St. Lawrence River Corridor and Their Role in the Source and Aquatic Fate of Toxic Contaminants. Water Poll. Res. J. Canada. Volume 21, No. 2, 1986.

Flood, K., The Effect of Effluent and Sediment Lead Loadings on Organolead Bioaccumulation by Yellow Perch Caged Downstream of a Tetraethyl Lead Plant. Ontario Ministry of the Environment, unpublished paper. November 1986.

Griffiths, M., Effects of Industrial Effluents on Water Quality, Sediments and Benthos of the St. Lawrence River at Maitland, Ontario. Ontario Ministry of the Environment, 1978.

Kuntz, K.W., Contaminants in Bottom Sediments of the St. Lawrence River in June 1975. Technical Bulletin #147. Inland Waters Directorate, Ontario Region, Environment Canada. May 1985.

Nriagu, J.O., Wong, H.K.T. and Coker, R.D., Particulate and Dissolved Trace Metals in Lake Ontario. Water Research, Vol. 15 pp. 91 to 96. Pergamon Press. 1981.

Ontario Ministry of the Environment, Handbook of Analytical Methods for Environmental Samples. Laboratory Services Branch and Applied Research Branch. December 1983.

Ontario Ministry of the Environment, Ministry of Natural Resources, Guide to Eating Ontario Sport Fish. 1986

Persaud, D and W.D. Wilkins., Evaluating Construction Activities Impacting on Water Resources. Ontario Ministry of the Environment. January 1976.

Sloterdijk, H.H., Toxic Substances in Lake St. Francis Sediments. Can. Tech. Rep. Fish. Aquat. Sci. 1368: pp. 249-264. 1985.

Sylvestre, A., Kuntz, K.W. and Warry, N.D., Water Quality at the Inlet to the St. Lawrence River, 1977 to 1983. Environment Canada. Inland Waters Directorate, draft report. September 1985.

Sylvestre, A., Organochlorines and Polyaromatic Hydrocarbons in the St. Lawrence River at Wolfe Island 1982-1984. Environment Canada, Inland Waters Directorate, draft report. March 1986.

Tseng, T. and King, L., Industrial Effluent Survey, Dupont Canada Inc. Maitland Ontario, June 21 - 25, 1982. Environment Canada, Environmental Protection Service. Unpublished report. October 1985.

Wilkins, W.D., Sediment Quality and Benthic Macroinvertebrates at 25 Transects in the Lake Ontario Nearshore Zone 1981. Manuscript report to the Ontario Ministry of the Environment. March 1985.

APPENDIX A SEDIMENT DESCRIPTION

Range	Depth North to South	Field Description	No. of Grabs Required	Lab Grain Size Analysis		
				% Sand >62 um	%Silt 62-3.73 um	%Clay <3.73 um
66	2m	-	3	91	4	5
	9m	Silt Clams	3	85	4	10
	18m	Silt Clams	3	47	0	52
	21m(d)	Silt Shells	3	47	0	52
	9m	Sand Silt	3	80	8	12
	2m	Sand	3	97	1	1
67	2m	Ooze, Ooze	6,6	79,74	15,18	6,7
	9m	Ooze	3	12	3	85
	18m	Sand Shells Silt	3	86	0	14
	23.5m(d)	Shells, Clay, Silt	3	69	2	28
	9m	-	15	83	3	14
	2m	Sand, Shells	45	-	-	-
68	2m	Sand	3	97	2	1
	9m	Ooze	3	56	10	33
	18m	Clay Fine Sand Shells	3	75	6	19
	25.5m(d)	Shells Clay	4	39	3	57
	9m	Shells	6	90	6	4
	2m	Sand Silt Shells	48	94	2	3
69	2m	Sand	7	96	3	1
	9m	Fine Sand, Silt	7	89	4	7
	18m	Shells Clay Sand	7	77	1	22
	25m(d)	Shells Clay	4	59	27	14
	9m	Sand Clay silt	3	90	3	6
	2m	Sand, Odourous	3	95	3	2
70	2m	Fine Sand	30+	96	2	1
	9m	Fine Sand, Silt, Shells	6	92	3	5
	18m	Shells Clay Some Sand	8	68	0	32
	24m(d)	-	7	62	0	37
	9m	Ooze, Ooze	4,4	71,72	0,1	29,27
	2m	Ooze	8	82	10	8
71	2m	Sand	4	91	7	2
	9m	Sand Silt	4	72	11	17
	18m	Sand Silt Shells	3	64	4	31
	22m(d)	Shells Silt Sand	7	25	2	72
	9m	Ooze, Muck	3	37	21	40
	2m	Sand Silt	9	97	2	1
72	2m	Fine Sand	3	92	6	2
	9m	Fine Sand	3	85	7	8
	18m	Sand Silt Coarse Gravel	5	55	4	40
	22m(d)	Coarse Sand Gravel Silt	6	59	7	34
	9m	Ooze	3	42	9	48
	2m	Sand	4	91	6	2

APPENDIX A SEDIMENT DESCRIPTION

Range	Depth North to South	Field Description	No. of Grabs Required	Lab Grain Size Analysis		
				% Sand >62 um	%Silt 62-3.73 um	%Clay <3.73 um
73	2m	Sand, Silt, Fine Sand	8,4	90,92	6,5	4,3
	9m	Gravel, Clay	4	83	7	9
	18m	Gravel, Clay	5	67	0	32
	22m(d)	Silt Clay Shells	6	40	0	32
	9m	Ooze	3	60	12	28
	2m	Ooze Foul Odour	3	97	1	1
74	2m	Fine Sand	6	76	20	3
	9m	Silty Sand	3	83	9	6
	18m	Clay Shells	3	57	3	39
	21m(d)	Gravel Shells	7	54	0	46
	9m	Sand Ooze	15	66	5	29
	2m	Sand & Fine Silt	8	94	4	2
75	2m	Fine Sand	3	85	10	3
76	2m	Fine Sand	3	75,75	11,8	14,17
	9m	Silt Clay	5	75	8	16
	18m	Silt Over Clay	6	54	0	45
	20m(d)	Clay & Shells	8	41	1	57
	9m	Ooze	3	28	7	64
	2m	Ooze	3	73	15	12
77	2m	Sand & Silt	3	95	3	2
78	2m	Sand & Organics	3	94,89	4,7	2,3
	9m	Ooze Very Fine Silt	8	58	1	40
	18m	Clay Cinders	3	68	4	28
	19m(d)	Clay Shells	3	45	1	52
	9m	Wood Fibres	3	51	36	12
79	2m	-	3	97	2	1
80	2m	Silt & Sand Organics	3	74	17	9
	9m	Silt & Sand	3	69	0	31
	9m	Sand & Gravel	70	97	2	1
81	18m(d)	Sand & Coarse Gravel	25	94	3	2
	9m	Fine Silt	20	80	9	8
	2m	Silt with Clams, Sand & Silt	3,3	88,85	6,1	6,13

(d) = deepest station on range

APPENDIX B - SEDIMENT CHEMISTRY

Range	Depth North to South	%Loss on Ignition	TOC mg/g	TP mg/g	TKN mg/g	SOL EX ug/g	Fe ug/g	As ug/g	Cd ug/g	Co ug/g	Cr ug/g	Cu ug/g	Hg ug/g	Ni ug/g	Zn ug/g	Pb ug/g
72	2m	1.2	4.5	0.5	0.3	190	4,700	0.79	<.1	2.7	8.9	6.3	0.03	2.7	11	21
	9m	2.3	12	0.6	0.6	1,430	6,100	1.64	0.14	11	18	26	0.1	6.7	25	130
	18m	7.1	12	1.5	0.6	380	38,000	43.05	<.1	17	29	12	0.05	24	68	18
	22m(d)	4.8	16	1.3	1.0	200	44,000	51.43	<.1	21	24	11	0.05	29	63	18
	9m	4.2	30	0.7	2.6	2,190	14,000	4.33	0.91	7.4	34	30	0.25	20	100	36
	2m	0.2	5.4	0.3	0.4	550	2,700	0.96	<.1	2	5.7	1.4	0.02	3.2	14	5.4
73	2m	1.9	6.4	0.5	0.4	600	3,300	0.7	<.1	2.7	8.5	8.4	0.03	2.6	12	25
	2m	3.7	5.8	0.4	0.3	480	3,900	0.87	<.1	2.6	9.0	6.2	0.03	2.5	11	20
	9m	4.9	17	0.9	1.6	2,050	7,400	2.08	0.48	5.2	17	22	0.11	7.3	39	100
	18m	6.2	13	1.6	1.0	290	44,000	49.35	<.1	17	28	10	0.06	26	70	23
	22m(d)	6.6	8.7	1.6	0.7	530	49,000	57.78	<.1	21	33	20	0.06	35	80	20
	9m	6.8	27	0.8	3.1	2,780	11,000	3.45	1.1	6.0	33	30	0.23	20	100	36
	2m	0.6	2.7	0.5	0.3	90	4,500	0.62	<.1	2.0	6.6	<0.5	0.03	3.2	11	46
74	2m	3.3	7.2	0.5	0.7	690	4,500	1.13	<.1	3.3	9.4	9.2	0.05	3.3	15	29
	9m	3.9	12.	0.6	0.5	550	6,300	0.7	0.26	3.4	12	7.6	0.05	5.5	24	33
	18m	5.6	13	1.5	0.8	440	37,000	44.36	<.1	17	28	12	0.05	26	71	16
	21m(d)	6.6	27	0.9	1.4	720	23,000	15.85	0.10	8.8	23	24	0.17	17	52	25
	9m	11.1	37	0.8	4.1	1,490	10,000	3.56	0.83	5.5	30	27	0.18	17	79	30
	2m	0.2	3.7	0.5	0.3	1,560	7,000	0.79	0.1	2.4	9.9	1.1	0.01	3.4	15	3.0
75	2m	2.1	8.2	0.7	0.7	320	5,200	0.87	<.1	3.5	9.0	9.5	0.03	3	15	20
76	2m	4.3	11	0.7	1.2	1,160	9,900	1.82	<.1	5.4	19.	11.	0.02	8.8	24	13
	2m	2.5	8	0.6	1.0	970	10,000	1.13	<.1	4.9	17	8.2	0.03	7.5	23	18
	9m	3.8	8	1.0	0.9	530	14,000	4.81	0.19	5.5	17	9.6	0.07	8.6	36	31
	18m	5.5	16	1.1	0.9	230	26,000	21.81	<.1	11	26	11	0.05	20	57	18
	20m(d)	5.6	12	1.5	0.7	590	47,000	40.95	<.1	19	33	19	0.06	36	80	20
	9m	14.9	46	1.0	4.3	2,010	17,000	5.72	1.3	9.3	47	44	0.3	27	130	47
	2m	6.9	19	0.4	1.1	1,140	4,200	1.69	0.19	3.0	11	6.4	0.05	5.1	29	9.9
77	2m	2.2	4.4	0.5	0.5	590	4,200	0.79	0.16	2.9	7.6	5.5	0.02	3.1	12	13
78	2m	1.2	5.0	0.6	0.4	370	4,600	0.79	0.15	2.8	7.7	4.5	0.01	3.1	12.0	9.9
	2m	0.2	5.4	0.6	0.5	270	5,000	0.96	0.15	3.2	7.9	5.0	0.02	3.8	13.0	12
	9m	0.4	6.6	0.9	0.8	490	20,000	9.86	0.31	9.7	33	17	0.08	17	68	20
	18m	2.9	4.7	1.8	0.8	290	49,000	54.43	<.1	19	28	16	0.05	28	71	18
	19m(d)	6.5	4.7	2.2	0.6	370	66,000	95.63	<.1	28	28	23	0.06	40	89	24
	9m	66.1	340	0.6	4.4	6,460	8,000	5.9	1.2	4.4	19	20	0.22	17	82	21
MOE Guidelines		6.0	-	1.0	2.0	1,500	10,000	8.0	1.0	50	25	25	0.3	25	100	50

APPENDIX B - SEDIMENT CHEMISTRY

Range	Depth North to South	%Loss on Ignition	TOC mg/g	TP mg/g	TKN mg/g	SOL EX ug/g	Fe ug/g	As ug/g	Cd ug/g	Co ug/g	Cr ug/g	Cu ug/g	Hg ug/g	Ni ug/g	Zn ug/g	Pb ug/g
79	2m	11.1	28	0.4	0.6	200	5,600	2.6	0.16	3.4	6.6	8.5	0.05	4.1	23	15
80	2m	1.4	13	0.7	1.5	790	8,000	1.9	0.36	4.9	18	18	0.09	9.2	38	30
	9m	1.3	2.6	1.1	0.4	230	20,000	4.54	0.17	11	32	17	0.04	17	53	37
	9m	1.0	1.7	0.4	0.2	350	8,600	1.13	0.1	2.8	7.6	2.	<.01	3.2	24	8.1
81	18m(d)	0.6	0.27	0.3	0.3	330	5,400	3.12	0.23	2.7	8.8	6.	<0.01	5.1	20	6.8
	9m	1.7	-	0.6	0.8	1,100	7,700	1.82	0.46	4.2	11	9.5	0.07	6.5	66	11
	2m	0.3	8.1	0.4	0.5	420	7,300	1.39	0.28	5.2	12	7.5	0.05	7.1	51	7.3
		1.4	4.6	0.4	0.3	330	9,600	0.96	0.21	5.4	17	8.0	0.03	9.1	43	5.9
MOE Guidelines		6.0	-	1.0	2.0	1,500	10,000	8.0	1.0	50	25	25	0.3	25	100	50

- underlined values equal or exceed MOE guidelines for open water disposal of dredge spoil.
- (d) = deepest station on range

APPENDIX C - SEDIMENT TRACE ORGANICS (all results in ng/g)

Range	Depth North to South	PCB	HCB	pp DDE	Dieldrin	Endrin	a BHC	g CHLOR-DANE	OXYCHLOR-DANE	pp DDD	DMDT	Endosulphan I	Endosulphan Sulphate
detection limit		20	1	1	2	4	1	2	2	5	5	2	4
66	2m	-	-	1.0	-	-	-	-	-	-	-	-	-
	9m	-	-	-	-	-	-	-	-	-	-	-	-
	18m	-	-	-	-	-	-	-	-	-	-	-	-
	deepest	-	-	1.0	10	-	-	-	-	-	-	-	-
	9m	-	-	1.0	8	-	-	-	-	-	-	-	-
	2m	-	-	-	-	-	-	-	-	-	-	-	-
67	2m	-	-	2,1	2,4	-	-	-	-	-	-	-	-
	9m	160(P40)	2	15	29	100	-	-	-	-	-	-	-
	18m	-	-	1	-	5	-	-	-	-	-	-	-
	deepest	-	1	3	5	-	-	-	-	-	-	-	-
	9m	-	-	1	5	-	-	-	-	-	-	-	-
	2m	-	-	-	3	-	-	-	-	-	-	-	-
68	2m	-	-	-	3	-	-	-	-	-	-	-	-
	9m	35(P54)	1	2	-	-	-	-	-	-	-	-	-
	18m	-	-	1	4	-	-	-	-	-	-	-	-
	deepest	-	-	1	5	-	-	-	-	-	-	-	-
	9m	-	-	-	19	-	-	-	-	-	-	-	-
	2m	-	-	-	5	-	-	-	-	-	-	-	-
69	2m	NA	-	-	-	-	-	-	-	-	-	-	-
	9m	NA	-	-	-	-	-	-	-	-	-	-	-
	18m	NA	-	-	-	-	-	-	-	-	-	-	-
	deepest	NA	-	-	-	-	-	-	-	-	-	-	-
	9m	NA	-	-	-	-	-	-	-	-	-	-	-
	2m	-	-	-	-	4	-	-	-	-	-	-	-
70	2m	-	-	9	-	-	-	-	-	-	-	-	-
	9m	-	-	-	-	-	-	-	-	-	-	-	-
	18m	-	-	-	-	-	-	-	-	-	-	-	-
	deepest	-	-	-	-	-	-	-	-	-	-	-	-
	9m	20,30(P40)	ND,2	-	-	-	-	-	-	-	-	-	-
	2m	-	-	-	-	-	-	-	-	-	-	-	-
71	2m	-	1	-	5	-	-	-	-	-	-	-	-
	9m	-	7	1	6	-	-	-	-	-	-	-	-
	18m	-	2	1	4	-	-	-	-	-	-	-	-
	deepest		1	1	5	-	-	-	-	-	-	-	-
	9m	75(P40)	1	5	8	45	-	-	-	-	-	-	-
	2m	-	-	-	3	-	-	-	-	-	-	-	-

APPENDIX C - SEDIMENT TRACE ORGANICS (all results in ng/g)

Range	Depth North to South	PCB	HCB	pp DDE	Dieldrin	Endrin	a BHC	g CHLOR-DANE	OXYCHLOR-DANE	pp DDD	DMDT	Endosulphan I	Endosulphan Sulphate
detection limit		20	1	1	2	4	1	2	2	5	5	2	4
72	2m	-	-	-	3	-	-	-	-	-	-	-	-
	9m	35(P40)	351	-	4	-	-	-	-	-	-	-	-
	18m	-	-	-	4	-	-	-	-	-	-	-	-
	deepest	-	2	-	11	-	2	-	2	-	-	27	-
	9m	25(P40)	-	6	3	-	-	-	-	-	-	-	-
	2m	-	-	-	2	-	-	-	-	-	-	-	-
73	2m	-	4,4	-	4,5	-	-	-	-	-	-	-	-
	9m	65(P40)	7	1	2	-	-	-	-	-	-	-	-
	18m	30(P40)	3	-	5	-	-	-	-	-	-	-	-
	deepest	55(P40)	3	-	-	-	-	-	-	-	-	-	-
	9m	85(P40)	6	7	3	-	-	-	-	-	-	-	-
	2m	-	-	-	3	-	-	-	-	-	-	-	-
74	2m	20(P40)	2	1	4	-	-	-	-	-	-	-	-
	9m	65(P40)	3	1	-	-	-	-	-	-	-	-	-
	18m	-	3	-	5	-	-	-	-	-	-	-	-
	deepest	-	1	1	-	-	-	-	-	-	-	-	-
	9m	110(P84)	8	17	-	-	-	-	-	-	-	-	-
	2m	-	1	-	5	-	-	-	-	-	-	-	-
75	2m	-	-	1	-	-	-	-	-	-	-	-	-
76	2m	-	1,2	1,ND	ND,4	-	-	-	-	-	-	-	-
	9m	25(P40)	2	2	2	-	-	-	-	-	-	-	-
	18m	-	2	1	4	-	-	-	-	-	-	-	-
	deepest	-	1	1	3	-	-	-	-	-	-	-	-
	9m	85(P40)	4	10	-	-	-	-	-	-	-	-	-
	2m	-	3	-	-	-	-	-	-	-	-	-	-
77	2m	-	-	-	2	-	-	-	-	-	-	-	-
78	2m	-	-	-	ND,2	-	-	-	-	-	-	-	-
	9m	-	1	1	6	-	-	-	-	-	-	-	-
	18m	-	-	-	7	-	-	-	-	-	-	-	-
	deepest	-	-	1	4	-	-	-	-	-	-	-	-
	9m	70(P40)	-	10	5	-	-	3	-	-	-	-	-
79	2m	-	-	-	6	-	-	-	-	-	-	-	-
80	2m	-	-	-	-	-	-	-	-	-	-	-	-
	2m	-	-	-	-	-	-	-	-	-	-	-	-
	9m	-	1	-	-	-	-	-	-	-	-	-	-
	9m	-	-	-	-	-	-	-	-	-	-	-	-
81	deepest	37(P40)	-	-	-	-	-	-	-	-	-	-	-
	9m	76(P48)	-	2	-	-	-	-	-	-	-	-	-
	2m	-	-	1,ND	-	-	-	-	-	-	-	-	-

(P 40) - PCB Resembled mixture of arochlor 1254 and 1260
(P 54) - PCB Resembled arochlor 1254
(P 84) - PCB Resembled mixture of arochlor 1248 and 1254
(P 48) - PCB Resembled arochlor 1248

ND or '-' not detected
NA - not analysed.